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QUARTERLY RELIABILITY STATUS REPORT

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ILLUSTRATIONS

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TABLES

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I. SPACECRAFT ANALYSIS

SPACECRAFT RELIABILITY APPORTIONMENT STUDY

SUMMARY

Analyses completed have established the preliminary Apollo subsystem mission success and crew safety reliability apportionments for the LOR mission. Current estimated subsystem reliabilities were also developed for each Apollo subsystem.

ANALYSIS

Overall spacecraft reliability analyses completed during the past quarter have established the preliminary Apollo subsystem mission success reliability apportionments based on the 8-day LOR nominal mission and crew safety reliability apportionments based on the 14-day LOR design maximum mission. It was necessary to analyze both the 8-day and the 14-day missions simultaneously, to optimize the over-all spacecraft configuration with respect to weight and performance while achieving the 0. 90 mission success and 0. 999 crew safety reliability requirements. These analyses, conducted with the Apollo reliability simulation model, yield the preliminary reliability requirements for the Apollo subsystems as shown in Table 1-1. The direct landing mission subsystem reliability apportionments for both crew safety and mission success, which were previously published in SID 62-557-1, are presented for comparison in Table 1-1.

The reliability requirements used in the LOR mission success apportionment analysis for the boosters and the LEM are the Work Statement reliability requirements of 0. 95 and 0. 984, respectively. The LEM crew safety reliability requirement used for the apportionment analysis was 0. 9995.

The Apollo reliability simulation model has also been used to derive both mission success and crew safety reliability estimates for the Apollo spacecraft subsystems. The predicted subsystem reliabilities were derived by utilizing current state-of-the-art component failure rates. The spacecraft equipment configurations derived in the apportionment analysis

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above, including electronic spares, were maintained in assessing the current predicted subsystem reliabilities. These numerics are displayed in Table 1-2 along with the reliability apportionments. The booster and LEM reliabilities used in the apportionment analyses were also utilized in the analysis of current predicted subsystem reliabilities. Table 1-2 shows that the predicted reliability and the LOR apportionments are equivalent for certain subsystems. Those critical subsystems for which a significant subsystem reliability improvement is necessary to achieve the requirement have been noted in the table. These critical areas will be discussed in the specific subsystem sections.

Table 1-1. Apollo Subsystem Direct Landing Versus LOR Mission Apportionments

Subsystem	Mission Success Reliability		Crew Safety Reliability	
	Direct Landing Apportionments	LOR Apportionments	Direct Landing Apportionments	LOR Apportionments
Structural and mechanical	0.990021	0.999945	0.999920	0.999945
Launch escape	0.997800	0.999989	0.999950	0.999950
Electrical power	0.995500	0.998600	0.999970	0.999970
Earth landing	0.999940	0.999940	0.999940	0.999940
Cryogenic storage	N.A.	0.999600	N.A.	0.999999
Service module reaction control	0.996000	0.999400	0.999970	0.999980
Command module reaction control	0.999960	0.999950	0.999960	0.999960
Environmental control	0.993500	0.990000	0.999700	0.999912
Service propulsion	0.999770	0.999200	0.999970	0.999970
Stabilization and control	0.995000	0.992600	0.999900	0.999990
Guidance and navigation	0.994000	0.985034	0.999920	0.999967
Communication and data	0.992500	0.99900	—	0.999998
Instrumentation	0.995700	0.999990	—	0.999999

The Apollo parts failure rates upon which subsystem predicted reliabilities in Table 1-2 are based were derived from the most current information available, including Martin, Avco and Minuteman parts handbooks. In addition, subcontractor inputs as well as developmental test data were utilized when applicable.

The mission reliability profiles for both the 8-day and the 14-day missions have been developed for both apportioned and predicted reliabilities. These profiles, which show the expected reliability degradation by mission phase, are included in Figures 1-1 and 1-2.

Table 1-2. LOR Apportioned and Predicted Reliabilities

Subsystem	Mission Success Reliability		Crew Safety Reliability	
	Apportioned	Predicted	Apportioned	Predicted
Structural and mechanical	0.999945	0.999713	0.999945	0.999960
Launch escape	0.999989	0.999989	0.999950	0.999950
Electrical power*	0.998600	0.998284	0.999970	0.999498
Earth landing	0.999940	0.999940	0.999940	0.999940
Cryogenic storage	0.999600	0.999600	0.999999	0.999999
Service module reaction control*	0.999400	0.995746	0.999980	0.999840
Command module reaction control*	0.999950	0.989297	0.999960	0.991252
Environmental control	0.990000	0.984762	0.999912	0.999912
Service propulsion*	0.999200	0.972900	0.999970	0.994500
Stabilization and control	0.992600	0.992600	0.999990	0.999990
Guidance and navigation	0.985034	0.985034	0.999967	0.999967
Communication and data	0.999000	0.999000	0.999998	0.999998
Instrumentation	0.999990	0.999990	0.999999	0.999999

*Subsystem reliability improvement is necessary to achieve reliability objectives

Mission success for the 8-day nominal mission shown in Table 1-2 is defined as the probability of completing the mission up to the end of lunar surface stay period No. 1 with no failures that would require an abort and the safe return of the crew to earth at any time following lunar surface stay period No. 1.

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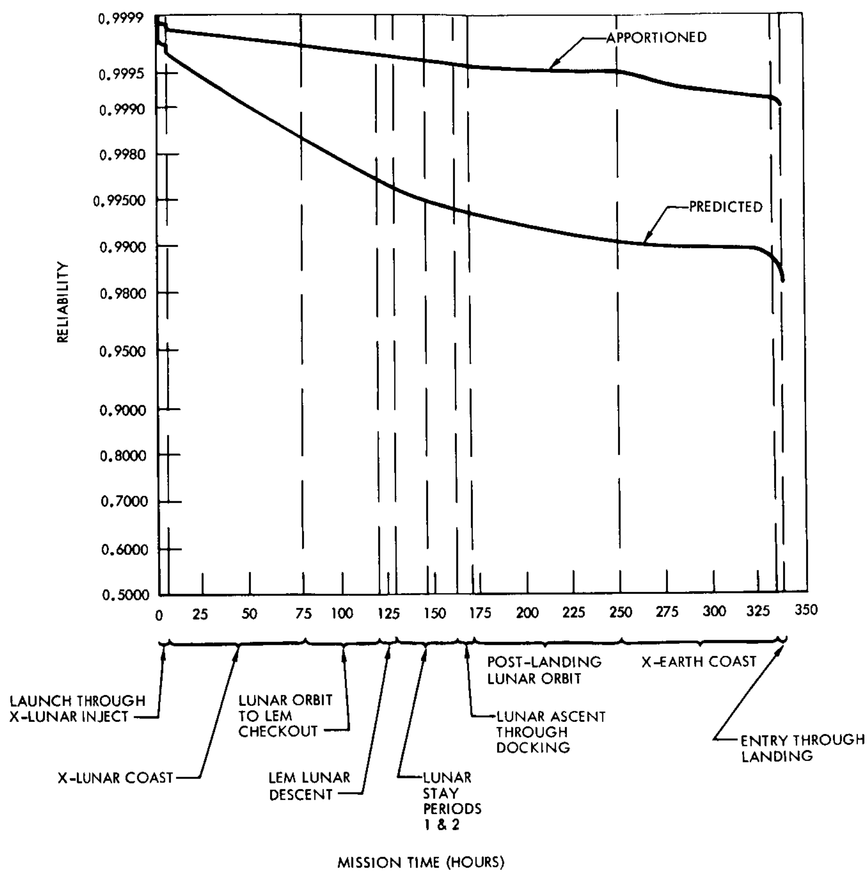

Figure 1-1. Apollo Mission Reliability Profile, 14-Day Crew Safety

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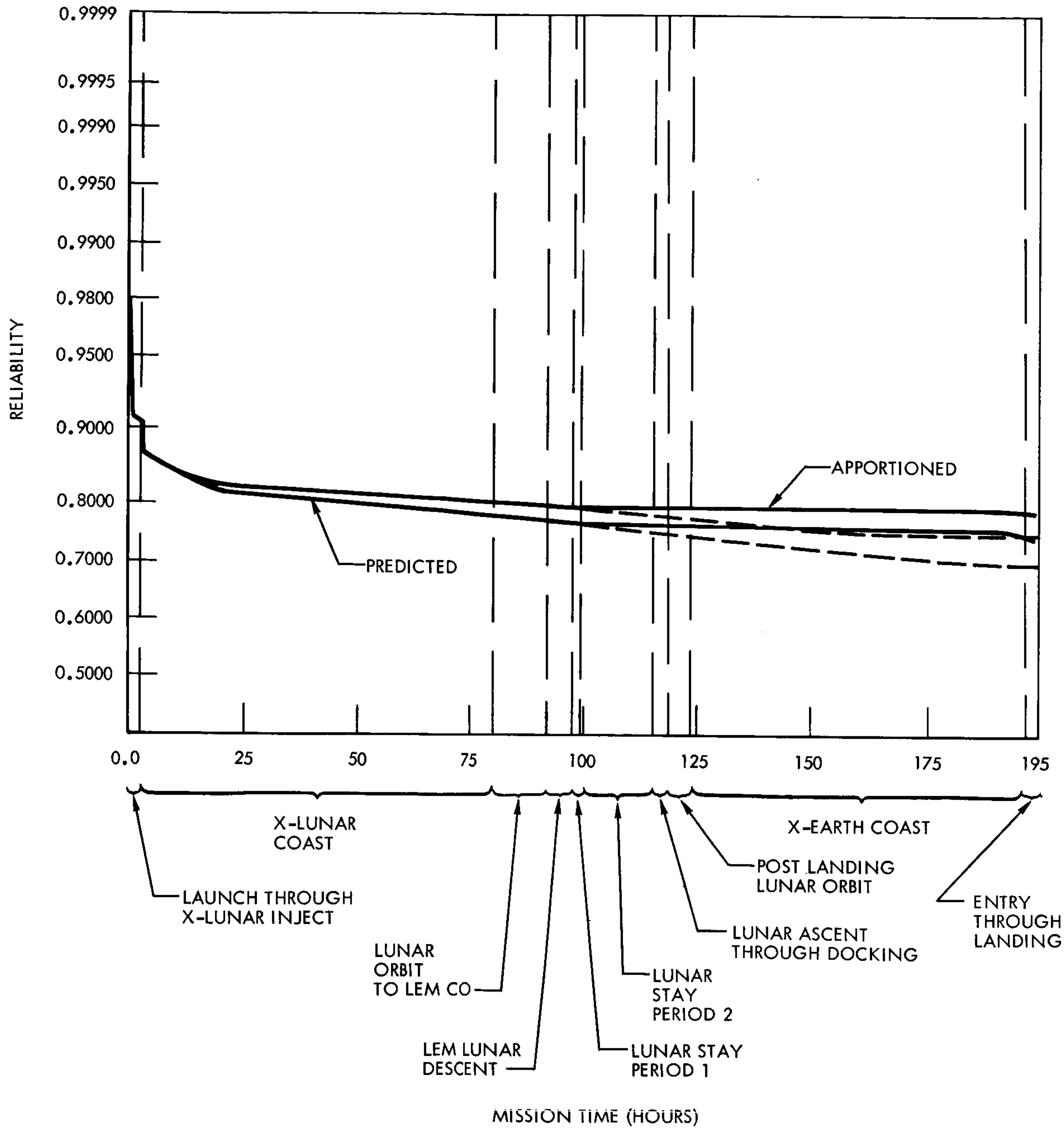

Figure 1-2. Apollo Mission Reliability Profile, 8-Day Mission Success

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APOLLO SPACECRAFT CREW SAFETY ANALYSIS

The spacecraft component criticalities described in SID 62-557-6 have been completely revised for all Apollo subsystems. The corresponding component sensor rankings also defined in SID 62-557-6 have been completed on the basis of current subsystem logic and mission requirements. These rankings are included in this report (Table 1-3).

Component criticality is defined as the probability of a component failing the mission in the crew safety mode of operation. These criticalities will be used by the crew safety system panel as a guide in determining the adequacy of current subsystem design and the need for possible design improvement required to meet the crew safety system objectives. Their primary value will be in directing further development effort on a subsystem should the need arise.

Component sensor rankings are defined as the total improvement in crew safety reliability that can be achieved by detecting a component failure and taking the appropriate corrective action. As such, these rankings will guide the crew safety system panel in selecting those sensors which will result in a maximum gain in reliability. For example, given a weight allotted to the instrumentation subsystem for sensing failures, the optimum gains in crew safety reliability for the allotted weight could be achieved by dividing the sensor ranking for each part by the weight of the sensing mechanism required to sense its failure and then using this quotient to select the sensors with the higher quotient until the allotted weight has been utilized. In addition, these quantitative measures of sensor influence on reliability will make possible comparisons between sensors and on-board spares which could result in both mission success and crew safety reliability gains.

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMAND MODULE REACTION CONTROL SUBSYSTEM			
Helium pressurization loop			
He storage tank	2	0.000244	0.0021
He fill valve	2	0.000000053	0.0000
He fill valve cap	2	0.000000053	0.0000
He filter	2	0.0000454	0.0001
He pressurization solenoid valve	4	0.0000000067	0.0000
He pressure regulator	8	0.0008704	0.0000
He pressurization tubing and fittings	2	0.027134	0.0001
Reactant supply loop			
Fuel tank	2	0.267898	0.0048
Oxidizer tank	2	0.267898	0.0048
Check valve	8	0.133228	0.0001
Relief valve	4	0.000000334	0.0000
Filter, relief valve	4	0.000000334	0.0000
Burst disk, relief valve	4	0.00000002	0.0000
Filter, oxygen or fuel loop	4	0.106796	0.0000
Burst disk, oxidizer loop	2	0.053398	0.0001
Burst disk, fuel loop	2	0.26699	0.0001
Squib valve, interconnects	2	0.133495	0.0000
Squib valve, fuel or oxygen purge	4	0.133495	0.0000
Vent valve	4	0.0000002	0.0000
Vent valve cap	4	0.0000002	0.0000
Fill valve	4	0.0000043	0.0000
Fill valve cap	4	0.0000043	0.0000
Fittings	2	0.905897	0.0002
Tubing	2	1.01216	0.0002
Solenoid valve	4	0.40035	0.0001

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMAND MODULE REACTION CONTROL SUBSYSTEM (Cont)			
Engine loop			
Flow meter	4	0.00000104	0.0000
Fitting group	2	0.00000016	0.0000
Tubing	2	0.00000024	0.0000
Engine	12	1.86583	0.0000
SERVICE MODULE REACTION CONTROL SUBSYSTEM			
Helium pressurization loop			
He tank	4	0.0085697	0.0001
Fill valve and cap assembly	4	0.000129	0.0001
Solenoid valve	8	0.0006205	0.0001
He pressure regulator	16	0.00114371	0.0001
Fuel or oxidizer supply loop			
Fill valve and cap assembly	8	0.000129	0.0001
Solenoid valve	8	0.001579	0.0001
Check valve assembly	8	0.00058	0.0001
Relief valve and burst disk assembly	8	0.000129	0.0001
Vent valve and cap assembly	8	0.000129	0.0001
Positive expulsion tank	8	0.014562	0.0002
Engine loop			
Tubing, each quad	4	0.002384	0.0001
Fittings, each quad	4	0.002384	0.0001
Engine	16	0.424300	0.0070

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
SERVICE PROPULSION SUBSYSTEM			
Reactant supply loop			
He tank	2	0.318555	0.0001
Fill valve and cap assembly	3	0.0063711	0.0000
Solenoid valve	2	0.001408	0.0001
He pressure regulator	4	0.063711	0.2949
Relief valve, burst disk and filter assembly		0.0127422	0.2948
Oxidizer or fuel tank	4	0.891795	0.0001
Vent valve and cap assembly	2	0.0063711	0.0000
Fill valve and cap assembly	2	0.0063711	0.0000
Heat exchanger	2	0.573335	0.0000
Check valve	8	0.127326	0.2949
Fuel flex line	1	0.25484	0.0000
Oxidizer flex line	1	0.25484	0.0000
Filter, oxygen or fuel	2	0.063711	0.0000
Orifice, oxygen or fuel	2	0.063711	0.0000
Propellant utilization assembly	1	1.656295	0.0000
Engine loop			
Solenoid valve	8	0.15928	0.1542
Valve actuator	4	0.128696	0.0000
Fuel valve	4	0.063074	0.2948
Oxidizer valve	4	0.063074	0.2948
Check valve	4	0.12424	0.2948
Injector	1	1.27397	0.0000
Gimbal bearing		2.0384	0.0000
Gimbal actuator	4	0.414122	0.0000
Lines and fittings		0.127422	0.0000

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
CRYOGENIC STORAGE SUBSYSTEM			
Fill valve with cap (O_2 or H_2)	4	0.000000003	0.0001
Vent valve with cap (O_2 or H_2)	4	0.000000003	0.0001
Purge valve with cap (O_2 or H_2)	2	0.000000003	0.0001
Tank (O_2 or H_2)	4	0.0079	0.0030
Valve switch (O_2 or H_2)	4	0.0117	0.0001
Solenoid valve (O_2 or H_2)	4	0.000003	0.0001
Relief valve (O_2 or H_2)	4	0.9448	0.0374
Check valve (O_2 or H_2)	4	0.00086	0.0004
Signal conditioner (O_2 or H_2)	8	0.0006	0.0001
Pressure transducer (O_2 or H_2)	4	0.00123	0.0002
Pressure gage (O_2 or H_2)	4	0.0015	0.0001
Density probe (O_2 or H_2)	4	0.00041	0.0001
Quantity gauge (O_2 or H_2)	4	0.00064	0.0001
Pressure switch (O_2)	2	0.0000001871	0.0016
Heater switch (O_2)	2	0.0000000374	0.0007
Motor switch (O_2)	2	0.00000015	0.0023
Heater element (O_2)	2	0.00022	0.0009
Heater fan (O_2 or H_2)	8	0.000000561	0.0001
Heater element (H_2)	2	0.000224	0.0009
Heater fan (H_2)	2	0.0000001122	0.0001
Pressure switch (H_2)	2	0.0000000374	0.0032
Heater switch (H_2)	2	0.0000000374	0.0014
Solenoid valve (FC shutoff)		0.000000000003	0.0001
Lines and fittings		0.5237	0.0000

[redacted]

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ENVIRONMENTAL CONTROL SUBSYSTEM			
Command module pressure and temperature control circuit			
Cabin outflow pressure regulator and negative relief valve	1	19.229	2.8220
Cabin heat exchanger	1	1.677	0.0000
Cabin temperature anticipator	1	0.00804	168.0000
Cabin temperature control	1	0.82896	16800.0000
Cabin temperature sensor	1	0.0083	168.0000
Cabin blower and enclosure	2	0.06786	1677.0000
Cabin pressure regulator	2	0.9854	1.4110
WATER GLYCOL CIRCUIT			
Check valve a	1	0.00003	0.0000
Check valve space radiator outlet b, c, d, e	4	0.99332	0.0000
Glycol pressure relief valve	2	0.00841	42.0000
Check valve	2	0.000044	8.4000
Glycol evaporator	1	1.6876	0.0000
Glycol shutoff valve	1	0.99283	0.0000
Cabin temperature control valve	1	1.0008	1680.0000
Cabin temperature control valve, manual override	1	0.93075	0.0000
Space radiator isolation and vent valve	4	0.99332	0.0000
Glycol temperature control unit	1	0.82899	16800.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
WATER GLYCOL CIRCUIT (Cont)			
Glycol temperature sensor	2	0.000003	168.0000
Glycol fill connection	2	0.000044	0.0000
Glycol shutoff valve a, b	2	0.000089	
Glycol shutoff valve c, d	2	0.000414	0.0000
Glycol shutoff valve g, h	2	0.992799	0.0000
Glycol shutoff valve f	1	0.0000295	0.0000
Glycol shutoff valve e, j	2	0.0148	0.0000
Glycol shutoff valve i	1	1.985599	0.0000
Glycol reservoir	1	0.00165	0.0440
Glycol pump a	1	7.9861	3680.0000
Glycol pump b	1	6.7292	3680.0000
Glycol temperature control valve	1	10.0075	1680.0000
Glycol temperature control valve manual override	1	0.89958	0.0000
Check valve	2	0.99292	0.0003
Glycol ducts and connections	1	0.9928	2.6200
Filter	1	0.9927	0.0000
Accumulator	1	0.01835	168.0000
Isolation valve	1	0.00165	0.0000
Check valve	2	0.40791	185.0000
WATER SUPPLY CIRCUIT			
Water supply quick disconnect	1	0.00000148	0.0000

[redacted]

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
WATER SUPPLY CIRCUIT			
Water supply quick disconnect cap	1	0.00000148	0.0000
Check valve a, b, e	3	0.33084	0.0000
Check valve c, d	2	0.00000148	0.0001
Check valve f	1	0.00083	0.0000
Suit evaporator water inflow control valve	1	5.0435	1680.0000
Suit evaporator water inflow control valve, manual override	1	0.92236	0.0000
Potable water tank	1	0.9925	0.0000
Water chiller	1	0.9925	0.0000
Waste water tank	1	0.9925	0.0000
Water shutoff valve a, b, c, d	4	0.00000074	0.0000
Water shutoff valve cap a, b, c, d	4	0.00000074	0.0000
Water tank pressure relief valve	1	0.00024	8.4001
Water tank pressure relief valve, manual override	1	0.000009	0.0000
Potable water supply assembly, heater	1	0.00993	0.0000
Potable water supply assembly, supply valve	1	0.00000295	0.0000
Water pressure relief valve	2	0.000502	42.0000
Manual selector valve	2	0.000103	0.0000
Pressure control valve	2	1.7343	1680.0000
Tank pressure relief valve	2	0.03711	92.4000
Manual selector valve	2	0.03826	0.0000

[redacted]

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
WATER SUPPLY CIRCUIT (Cont)			
Freon storage tank	1	9.925	0.0000
Freon storage assembly valve	1	0.00083	0.0000
Water supply circuit ducts and connections	1	0.9925	1.3100
ENVIRONMENTAL CONTROL SUBSYSTEM			
Oxygen supply circuit			
Back pack supply shutoff valve	1	0.02187	0.0000
Back pack supply cap	1	0.02068	0.0000
Relief valve	2	0.02674	0.0000
Regulator	2	1.7096	840.0000
Selector valve	2	0.01678	0.0000
O_2 supply valve manual	1	0.99271	0.0000
Emergency O_2 inflow control valve	2	0.00000148	8.4000
Selector valve	1	0.00000295	0.0000
O_2 pressure regulator valve	2	1.71172	840.0000
Check valve	2	0.01191	0.0000
Relief valve	2	0.035324	8.4000
Selector valve	2	0.01696	0.0000
O_2 supply ducts and connections	1	1.09199	0.1310
Pressure suit circuit			
Return air check valve	2	0.09925	0.0000
Debris trap, filter	1	0.00334	0.0000
Debris trap, bypass valve	1	0.99425	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ENVIRONMENTAL CONTROL SUBSYSTEM (Cont)			
Suit circuit compressor A	1	13.7185	3680.0000
Suit circuit compressor B	1	13.6144	3680.0000
Suit circuit compressor check valve	2	0.78437	184.0000
CO_2 and odor absorber removable container	1	0.99259	0.0000
CO_2 and odor absorber isolation valve	1	1.98519	0.0000
CO_2 and odor absorber canister	2	0.000163	0.8400
CO_2 and odor absorber check valve	2	0.016827	84.0000
Suit bypass valve	1	0.00009	8.4000
Suit bypass valve, manual shutoff	1	0.00009	0.0000
Suit air temperature sensor	1	0.00804	168.0000
Suit air temperature control	1	0.83044	16800.0000
Suit evaporator temperature sensor	1	0.00804	168.0000
Suit evaporator temperature sensor	1	0.83044	16800.0000
Regenerative heat exchanger assembly	1	14.8894	0.0000
Regenerative heat exchanger bypass valve	1	4.96296	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ENVIRONMENTAL CONTROL SUBSYSTEM (Cont)			
Regenerative heat exchanger bypass valve, actuator	1	0.08055	1680.0000
Regenerative heat exchanger bypass valve, manual override	1	0.92239	0.0000
Regenerative heat exchanger, accumulator	3	0.09958	10.6276
Suit circuit flow limiters	1	0.00000295	0.0000
Suit hose connector package	4	0.99259	0.0000
Suit circuit ducts and connections	1	0.99259	1.3100
LAUNCH ESCAPE SUBSYSTEM			
Launch escape motor			
Initiator	1	0.059948	3.6946
Pyrogen igniter	1	3.102261	191.1912
Propellant	1	3.102261	191.1912
Liner	1	0.620227	38.2244
Case	1	0.620227	38.2244
Nozzle	4	1.240516	76.4525
Tower jettison motor			
Initiator	1	0.060005	3.6981
Pyrogen igniter	1	0.263063	16.2125
Propellant	1	3.370135	207.7001
Liner	1	0.745412	45.9395
Case	1	0.745412	45.9395
Nozzle	2	1.252018	77.1614

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
LAUNCH ESCAPE SUBSYSTEM (Cont)			
Pitch control motor			
Initiator	1	0.059718	0.0000
Pyrogen igniter	1	0.017915	0.0000
Propellant	1	0.0059718	0.0000
Liner	1	0.0059718	0.0000
Case	1	0.0059718	0.0000
Nozzle	2	0.131382	0.0000
Tower structure		1.4973	92.2780
Explosive bolts		1.9973	123.0928
ELECTRICAL POWER SUBSYSTEM			
Fuel cell loop			
Diode, CR-19	1	0.0000321	0.0000
Diode, CR-20	1	0.0000321	0.0000
Diode, CR-21	1	0.0000321	0.0000
Diode, CR-22	1	0.00000321	0.0000
Diode, CR-23	1	0.0000321	0.0000
Diode, CR-24	1	0.0000321	0.0000
Circuit breaker, CB-7	1	0.00738	0.0001
Circuit breaker, CB-71	1	0.00738	0.0001
Circuit breaker, CB-55	1	0.00738	0.0001
Circuit breaker, CB-58	1	0.00738	0.0001
Circuit breaker, CB-8	1	0.00738	0.0001
Circuit breaker, CB-72	1	0.00738	0.0001
Circuit breaker, CB-56	1	0.00738	0.0001

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ELECTRICAL POWER SUBSYSTEM (Cont)			
Circuit breaker, CB-59	1	0.00738	0.0001
Circuit breaker, CB-9	1	0.00738	0.0001
Circuit breaker, CB-73	1	0.00738	0.0001
Circuit breaker, CB-57	1	0.00738	0.0001
Circuit breaker, CB-60	1	0.00738	0.0001
Switch, S-21	1	0.00988	0.0001
Switch, S-27	1	0.00988	0.0001
Switch, S-45	1	0.00988	0.0001
Switch, S-24	1	0.00988	0.0001
Switch, S-28	1	0.00988	0.0001
Switch, S-46	1	0.00988	0.0001
Switch, S-25	1	0.00988	0.0001
Switch, S-29	1	0.00988	0.0001
Switch, S-47	1	0.00988	0.0001
Switch, S-10	1	0.0000321	0.0000
Switch, S-11	1	0.0000321	0.0000
Switch, S-12	1	0.0000321	0.0000
Switch, S-13	1	0.0000321	0.0000
Switch, S-14	1	0.0000321	0.0000
Switch, S-15	1	0.0000321	0.0000
Relay, K-10	1	0.0000321	0.0000
Relay, K-11	1	0.0000321	0.0000
Relay, K-12	1	0.0000321	0.0000
Relay, K-13	1	0.0000321	0.0000
Relay, K-14	1	0.0000321	0.0000
Relay, K-15	1	0.0000321	0.0000
O_2 pressure regulator valve	3	0.44055	0.4135

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ELECTRICAL POWER SUBSYSTEM (Cont)			
O_2 purge control valve	3	0.00321	0.0030
H_2 pressure regulator valve	3	0.44055	0.4135
H_2 bypass control valve	3	0.14328	0.1344
H_2 pump and motor assembly	3	0.17643	0.1655
H_2 regenerator	3	0.04277	0.0411
H_2 condenser	3	0.04277	0.0411
H_2 purge control valve	3	0.00321	0.0030
N_2 pressure regulator	3	0.011013	0.1033
N_2 purge control valve	3	0.00321	0.0030
N_2 tank	3	0.00106	0.0009
Module jacket	3	0.00321	0.0030
N_2 control valve	3	0.00000536	0.0001
N_2 fill valve	3	0.00000536	0.0001
Fuel cell stack	3	1.2222	1.1468
Glycol accumulator	3	0.09835	0.0923
Glycol pump	3	0.17643	0.1655
O_2 preheater	3	0.02246	0.0210
H_2 preheater	3	0.02246	0.0210
Glycol quick disconnect	3	0.00000536	0.0001
Glycol control valve	3	0.00000536	0.0001
Radiator	3	0.00321	0.0030
Glycol regenerator	3	0.04384	0.0411
Glycol bypass control valve	3	0.087682	0.0823
Shock mounts, each fuel cell	3	0.04384	0.0411

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ELECTRICAL POWER SUBSYSTEM (Cont)			
Fuel cell loop			
Tubing and mechanical connections, each fuel cell	3	5. 010692	0. 0101
Wiring and electrical terminals, each fuel cell	3	0. 010692	0. 0101
D-C bus loop			
D-C main bus A	1	0. 02246	5. 0000
D-C main bus B	1	0. 02246	5. 0000
Circuit breaker, CB-1	1	0. 01482	1. 6800
Circuit breaker, CB-21	1	0. 01482	1. 6800
Circuit breaker, CB-37	1	0. 01482	1. 6800
Circuit breaker, CB-85	1	0. 01482	1. 6800
Circuit breaker, CB-83	1	0. 01482	1. 6800
Circuit breaker, CB-29	1	0. 01482	1. 6800
Circuit breaker, CB-27	1	0. 01482	1. 6800
Circuit breaker, CB-23	1	0. 01482	1. 6800
Circuit breaker, CB-25	1	0. 01482	1. 6800
Circuit breaker, CB-81	1	0. 01482	1. 6800
Circuit breaker, CB-89	1	0. 01482	1. 6800
Circuit breaker, CB-87	1	0. 01482	1. 6800
Circuit breaker, CB-3	1	0. 01482	1. 6800
Circuit breaker, CB-5	1	0. 01482	1. 6800
Circuit breaker, CB-79	1	0. 01482	1. 6800
Circuit breaker, CB-77	1	0. 01482	1. 6800
Circuit breaker, CB-75	1	0. 01482	1. 6800
Circuit breaker, CB-17	1	0. 01482	1. 6800
Circuit breaker, CB-2	1	0. 01482	1. 6800
Circuit breaker, CB-128	1	0. 01482	1. 6800
Circuit breaker, CB-38	1	0. 01482	1. 6800
Circuit breaker, CB-86	1	0. 01482	1. 6800
Circuit breaker, CB-84	1	0. 01482	1. 6800
Circuit breaker, CB-30	1	0. 01482	1. 6800
Circuit breaker, CB-28	1	0. 01482	1. 6800

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ELECTRICAL POWER SUBSYSTEM (Cont)			
D-C bus loop			
Circuit breaker, CB-24	1	0.01482	1.6800
Circuit breaker, CB-26	1	0.01482	1.6800
Circuit breaker, CB-82	1	0.01482	1.6800
Circuit breaker, CB-90	1	0.01482	1.6800
Circuit breaker, CB-88	1	0.01482	1.6800
Circuit breaker, CB-4	1	0.01482	1.6800
Circuit breaker, CB-6	1	0.01482	1.6800
Circuit breaker, CB-80	1	0.01482	1.6800
Circuit breaker, CB-78	1	0.01482	1.6800
Circuit breaker, CB-76	1	0.01482	1.6800
Circuit breaker, CB-18	1	0.01482	1.6800
Diode, CR-13	1	0.22135	1.5000
Diode, CR-14	1	0.22135	1.5000
Diode, CR-17	1	0.22135	1.5000
Diode, CR-18	1	0.22135	1.5000
Inverter loop			
Circuit breaker, CB-13	1	0.043852	3.36000
Circuit breaker, CB-14	1	0.043852	3.36000
Circuit breaker, CB-61	1	0.043852	3.36000
Circuit breaker, CB-62	1	0.043852	3.36000
Circuit breaker, CB-15	1	0.042761	3.36000
Circuit breaker, CB-16	1	0.042761	3.36000
Circuit breaker, CB-63	1	0.042761	3.36000
Switch, S-1	1	0.00587	5.04000
Switch, S-2	1	0.00587	5.04000
Switch, S-3	1	0.00577	5.04000
Switch, S-19	1	0.00577	5.04000
Switch, S-4	1	0.0000321	0.0001
Switch, S-5	1	0.0000321	0.0001
Switch, S-6	1	0.0000321	0.0001
Switch, S-7	1	0.0000321	0.0001
Switch, S-8	1	0.0000321	0.0001
Switch, S-9	1	0.0000321	0.0001

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ELECTRICAL POWER SUBSYSTEM (Cont)			
Relay, K-1	1	0.00523	3.3600
Relay, K-2	1	0.00523	3.3600
Relay, K-3	1	0.00504	3.3600
Relay, K-4	1	0.0000321	0.0001
Relay, K-5	1	0.0000321	0.0001
Relay, K-6	1	0.0000321	0.0001
Relay, K-7	1	0.0000321	0.0001
Relay, K-8	1	0.0000321	0.0001
Relay, K-9	1	0.0000321	0.0001
Inverter 1	1	1.4532	5880.0000
Inverter 2	1	1.4532	5880.0000
Inverter 3	1	1.4532	138.2976
A-C bus loop			
A-C bus 1	1	0.01764	5.0000
A-C bus 2	1	0.01764	5.0000
Circuit breaker, CB-129	1	0.0000642	0.0001
Circuit breaker, CB-127	1	0.0000642	0.0001
Circuit breaker, CB-54	1	0.0000642	0.0001
Circuit breaker, CB-52	1	0.0000642	0.0001
Circuit breaker, CB-31	1	0.01123	1.6800
Circuit breaker, CB-131	1	0.01123	1.6800
Circuit breaker, CB-69	1	0.01123	1.6800
Circuit breaker, CB-130	1	0.01123	1.6800
Circuit breaker, CB-66	1	0.01123	1.6800
Circuit breaker, CB-67	1	0.01123	1.6800
Circuit breaker, CB-68	1	0.01123	1.6800
Circuit breaker, CB-32	1	0.01123	1.6800
Circuit breaker, CB-74	1	0.01123	1.6800
Circuit breaker, CB-109	1	0.000000321	0.0001
Circuit breaker, CB-110	1	0.000000321	0.0001
Circuit breaker, CB-111	1	0.000000321	0.0001
Circuit breaker, CB-112	1	0.000000321	0.0001

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
ELECTRICAL POWER SUBSYSTEM (Cont)			
Circuit breaker, CB-113	1	0.000000321	0.0001
Circuit breaker, CB-114	1	0.000000321	0.0001
Circuit breaker, CB-115	1	0.000000321	0.0001
Circuit breaker, CB-116	1	0.000000321	0.0001
Circuit breaker, CB-117	1	0.000000321	0.0001
Circuit breaker, CB-118	1	0.000000321	0.0001
Circuit breaker, CB-119	1	0.000000321	0.0001
Circuit breaker, CB-120	1	0.000000321	0.0001
Circuit breaker, CB-121	1	0.000000321	0.0001
Circuit breaker, CB-122	1	0.000000321	0.0001
Circuit breaker, CB-123	1	0.000000321	0.0001
Circuit breaker, CB-124	1	0.000000321	0.0001
Circuit breaker, CB-125	1	0.000000321	0.0001
Circuit breaker, CB-126	1	0.000000321	0.0001
Switch, S-31	1	0.015173	2.5200
Switch, S-32	1	0.015173	2.5200
Switch, S-33	1	0.015173	2.5200
Switch, S-44	1	0.015173	2.5200
Battery subsystem			
Reentry battery system	1	0.35447	532.0000
Postlanding battery system	1	0.31983	532.0000
EARTH LANDING SUBSYSTEM			
Sequencer battery	2	5.6877	2.3274
Pyro battery	2	2.84196	0.5811
Forward heat shield jettison baroswitch	4	0.167438	0.0000
Forward heat shield jettison relay	2	0.01009	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
EARTH LANDING SUBSYSTEM (Cont)			
Forward heat shield jettison cartridge	2	1.67587	0.0000
Forward heat shield jettison gas generator	2	0.16744	0.0000
Forward heat shield jettison thruster	4	0.167438	0.0000
Forward heat shield tension tie	4	0.7475	0.0000
Pilot chute release time delay	4	0.000001	0.0000
Pilot chute release baroswitch	4	0.0000037	0.0000
Pilot chute release relay	2	0.00000022	0.0000
Pilot chute release cartridge	6	0.0000075	0.0000
Pilot chute mortar	3	0.002242	0.0000
Pilot chute	3	0.002242	0.0000
Main chute	3	0.04485	0.0000
Disconnect inertia switch	4	0.06989	0.0000
Main chute disconnect	1	7.4741	0.0000
Drogue time delay	4	0.00007	0.0000
Drogue relay	2	0.0000022	0.0000
Drogue cartridge	2	0.00034	0.0000
Drogue mortar	2	0.000034	0.0000
Drogue chute	2	0.00034	0.0000
Drogue release	1	0.000224	0.0000
STABILIZATION AND CONTROL SUBSYSTEM			
APK-accelerometer and electronics			
APAC-accelerometer		0.0001	0.0000
BATCD-temperature control amplifier		0.0001	0.0000
APAD-accelerometer amplifier		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
ASFI-attitude set FDAI align			
ASFI-attitude set FDAI align		0. 0001	0. 0000
BMPY-body mounted pitch, yaw gyro			
BMAGB-attitude gyro		14. 1721	846. 012
BMAGC-attitude gyro		14. 1721	846. 012
BMBAB-buffer amplifier		0. 0011	6. 0708
BMBAC-buffer amplifier		0. 0011	6. 0708
BATCB-temperature control/indicator amplifier		0. 0037	12. 6433
BATCC-temperature control/indicator amplifier		0. 0037	12. 6433
BMTAB-torque amplifier		0. 0093	9. 7282
BMTAC-torque amplifier		0. 0093	9. 7282
BMML-mode logic relay		0. 0171	73. 0185
BMTI-temperature indicator logic		0. 0025	9. 9746
BMPS-power supply		0. 3984	13. 1475
BMR-body-mounted roll gyro			
BMAGA-attitude gyro		14. 1721	846. 0124
BMBAA-buffer amplifier		0. 0011	6. 0708
BATCA-temperature control/indicator amplifier		0. 0037	12. 6433
BMTAA-torque amplifier		0. 0093	9. 7282
ECAR-electronic control assembly, roll			

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
ECMR-mode and jet selection logic, roll		1.6867	26.1271
ECPSA-d-c power supply		2.4920	21.2286
EGJSA-jet summing amplifier		0.0288	3.5345
ECJAA-jet switching amplifier		0.1204	7.1241
ECPY-electronic control assembly, pitch yaw			
ECMP-mode selection logic, pitch		2.1750	34.6297
ECMY-mode selection logic, yaw		2.5137	37.6876
ECPSB-d-c power supply		2.4920	21.2286
ECPSC-d-c power supply		2.4920	21.2286
ECJSB-jet summing amplifier		0.0288	3.5345
ECJSC-jet summing amplifier		0.0288	3.5345
ECJAB-jet switching amplifier		0.1204	7.1241
ECJAC-jet switching amplifier		0.1204	7.1241
ECIP-electronic control assembly, auxiliary power supply		0.0001	7.476
ETIN-thrust vector integrator			
ETINA-integrator assembly		0.0080	0.0018

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
ETINB-integrator assembly		0.0080	0.0018
ETPY-thrust vector pitch yaw assembly			
ETSAA-summing amplifier		0.0009	20.9800
ETSAB-summing amplifier		0.0009	20.9800
ETSPA-servo power and amplifier		0.0001	0.0000
ETSPB-servo power and amplifier		0.0001	0.0000
ETADA-amplifier demodulator		0.0001	0.0000
ETADB-amplifier demodulator		0.0001	0.0000
ETSPC-servo power and amplifier		0.0001	0.0000
ETSPD-servo power and amplifier		0.0001	0.0000
ETADC-amplifier demodulator		0.0001	0.0000
ETADD-amplifier demodulator		0.0001	0.0000
FDAE-attitude error indicator			
FDAE-attitude error display		0.0001	1.3130
FDRE-roll error		0.0001	2.8860
FDYE-pitch yaw error		0.0001	0.3000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
FDAI-total attitude indicator			
FDTA-total attitude display		1. 0800	1868. 3980
FDTAA-roll attitude		0. 0986	198. 6710
FDTAB-pitch attitude		0. 0986	58. 1720
FDTAC-yaw attitude		0. 0986	198. 6710
FDAM-flight director attitude indicator shared components		0. 0106	3. 4440
FDRI-angular rate indicator			
FDAR-angular rate display		0. 0041	0. 0091
FPYR-roll error		0. 0011	0. 0000
FDRR-roll rate and relays		0. 0015	0. 0000
FGPS-FDAI and gimbal position display power supply			
FDGP-FDAI-GPI power supply		2. 1553	30. 3310
FGSC-shared components (FDRI and GPI)		1. 4208	386. 9380
GCPY-G and C demodulator, pitch, yaw			
GCDAB-demodulator amplifier		0. 1855	70. 7410

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Table 1-3. Preliminary Apollo Subsystems Components Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
GCDAC-demodulator amplifier		0.1855	70.7410
GCR-G and C demodulator, roll			
GCDAA-demodulator amplifier		0.1855	70.7410
GCU-attitude gyro coupling unit			
GCEM-roll electro mechanical assembly		0.0161	0.0651
GCPY-pitch yaw electro mechanical assembly		0.0238	0.0962
GCGC-400-cps regulator and generator		0.0016	0.0033
GCPC-pulse counter		0.0008	0.0033
GCRS-resolver a-c supply		0.0008	0.0033
GCLDA-amplifier level detector		0.0009	0.0033
GCLDB-amplifier level detector		0.0009	0.0033
GCLDC-amplifier level detector		0.0009	0.0033
GCUD-demodulator		0.0028	0.0133
GCMLA-step motor control logic		0.0011	0.0033
GCMLB-step motor control logic		0.0011	0.0033
GCMLC-step motor control logic		0.0011	0.0033
GCSW-square wave reference and gating		0.0012	0.0049

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Table 1-3. Preliminary Apollo Subsystems Components Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
GPID-gimbal position display and electronics			
GPDP-gimbal position panel		0.0001	0.1920
GPPY-pitch, yaw electronics		0.0001	0.0960
GPIN-gimbal position dials		0.0027	44.9560
LDT-level detector (0.05 g switch)		0.0001	0.0000
RDPI-rate gyro demodulator, pitch, yaw			
RGDAB-rate stick demodulator amplifier		0.7233	99.0700
RGDAC-rate stick demodulator amplifier		0.7233	99.0700
RDR-rate gyro demodulator, roll		0.7233	99.0700
RGPY-rate gyro, pitch, yaw			
RGPKB-rate gyro		4.8369	296.1430
RGPKC-rate gyro		4.8369	296.1430
RGEL-rate gyro electronics		0.0012	0.0755
RGR-rate gyro, roll			
RGPKA-rate gyro		4.8369	296.1430

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
RJDC-reaction jet driver assembly, C/M, S/M			
RJDSA-jet driver		0.0001	0.0000
RJDSB-jet driver		0.0001	0.0000
RJDSC-jet driver		0.0001	0.0000
RJDSD-jet driver		0.0001	0.0000
RJDSE-jet driver		0.0001	0.0000
RJDSF-jet driver		0.0001	0.0000
RJDSG-jet driver		0.0001	0.0000
RJDSH-jet driver		0.0001	0.0000
RJDSI-jet driver		0.0001	0.0000
RJDSJ-jet driver		0.0001	0.0000
RJDSK-jet driver		0.0001	0.0000
RJDSL-jet driver		0.0001	0.0000
RJDSM-jet driver		0.0001	0.0000
RJDSN-jet driver		0.0001	0.0000
RJDSO-jet driver		0.0001	0.0000
RJDSP-jet driver		0.0001	0.0000
SBPY-SCS control panel backup rate, pitch, yaw			
SBPY-backup rate, pitch and yaw switch		0.0001	0.0003
SBR-SCS control panel backup rate, roll			
SBR-backup rate, roll switch		0.0001	0.0003
SBUE-SCS control panel backup entry switch			
SBUE-backup entry switch		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
SCMS-SCS control panel, mode select			
SCSS-mode select switch		0.2117	1312.1020
SCRP-mode select relay package		0.2117	79.0150
TRD-three axis rotational control, direct			
TRMSA-mechanical system		0.0001	0.0000
TRDA-direct electronics		0.0001	0.0000
TRMSB-mechanical system		0.0001	0.0000
TRDB-direct electronics		0.0001	0.0000
TRN-three axis rotational control, normal			
TRMSA-mechanical system		0.0001	0.0000
TRMSB-mechanical system		0.0001	0.0000
TRNA-normal system		0.0001	0.0000
TRNB-normal system		0.0001	0.0000
DVU-delta velocity direct ullage		0.0001	0.0000
DVD-delta velocity display		0.0001	0.0000
DVF-delta velocity thrust off		0.0001	0.0000
DVO-delta velocity thrust on		0.0001	0.0000
DVC-delta velocity comparator		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
STABILIZATION AND CONTROL SUBSYSTEM (Cont)			
ECET-engine thrust electronics		0.0001	0.0000
TCT-translational control, translational		0.0001	0.0000
TCO-translational control, sps off switch		0.0001	0.0000
GUIDANCE AND NAVIGATION SUBSYSTEM			
AGC-Apollo guidance computer			
AGSRA-string R		0.0042	0.9140
AGSRB-string R		0.0042	0.9140
AGSRC-string R		0.0042	0.9140
AGSRD-string R		0.0042	0.9140
AGSSA-string S		0.0042	0.9140
AGSSB-string S		0.0042	0.9140
AGSSC-string S		0.0042	0.9140
AGSSD-string S		0.0042	0.9140
AGSTA-string T		0.0042	0.9140
AGSTB-string T		0.0042	0.9140
AGSTC-string T		0.0042	0.9140
AGSTD-string T		0.0042	0.9140
AGCO-oscillator		0.0014	0.7978
AGFD-failure detection		0.0033	1.4622
AGCT-control		0.0023	1.8025
AGPSA-power switch		0.7934	2.3034
AGPSB-power switch		0.7934	2.3034
AGDS-driver service		0.0033	2.3034
AGCS-current switch		2.2390	8.2788
AGEM-erasable memory		8.0301	72.8118
AGEDA-erasable memory drive		0.3789	0.7978

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
AGEDB-erasable memory drive		0.3789	0.7978
AGSAA-sense amplifier		0.0638	6.8366
AGSAB-sense amplifier		0.0638	6.8366
AGTS-strand selector		0.0075	3.4515
AGRDA-rope driver		0.0272	5.2208
AGRDB-rope driver		0.0272	11.5970
AGASA-arithmetic stick		0.8379	11.5970
AGASB-arithmetic stick		0.8379	11.5970
AGASC-arithmetic stick		0.8379	11.5970
AGASD-arithmetic stick		0.8379	11.5970
AGASE-arithmetic stick		0.8379	11.5970
AGASF-arithmetic stick		0.8379	11.5970
AGASG-arithmetic stick		0.8379	11.5970
AGASH-arithmetic stick		0.8379	11.5970
AGASI-arithmetic stick		0.8379	11.5970
AGASJ-arithmetic stick		0.8379	11.5970
AGASK-arithmetic stick		0.8379	11.5970
AGASL-arithmetic stick		0.8379	11.5970
AGASM-arithmetic stick		0.8379	11.5970
AGASN-arithmetic stick		0.8379	11.5970
AGASO-arithmetic stick		0.8379	11.5970
AGASP-arithmetic stick		0.8379	11.5970
AGGS-GSA service		0.1032	11.5970
AGCP-parity		0.1032	11.5970
AGBK-bank		0.1032	11.5970
AGRP-RUPT priority		0.1060	12.3574
AGRA-rope address		0.0722	0.9280
AGEH-erasable memory hardware		0.1032	11.2970
AGTL-telemetry		3.3949	12.3574
AGRC-ring counter		0.2509	11.5970
AGSCA-scaler		0.1505	11.5970
AGSCB-scaler		0.1505	11.5970
AGPC-time pulse counter		0.0788	10.2550
AGCA-control pulse		0.0910	11.2298

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
AGCB-control pulse		0.0910	11.2298
AGCC-control pulse		0.0910	11.2298
AGSQ-SQ complex (register)		0.1032	11.5970
AGID-instruction decoder		0.0830	10.5621
AGKS-center priority service		0.1777	11.2298
AGCKA-center priority		0.1538	11.2970
AGCKB-center priority		0.1538	11.2970
AGAL-alarms		0.0938	11.2298
AGCR-rate		0.1097	12.3574
AGIFA-interface		1.5469	5.2208
AGIFB-interface		1.5469	5.2208
AGIFC-interface		1.5469	5.2208
PSLW-+3-v dc 3-amp power supply		3.1018	0.7970
PSLY-+3-v dc 20-amp power supply		3.1018	0.7970
PSZL-+13-v dc power supply		3.1018	0.7970
CDCM-IMU, manual control and display			
CDMCA-manual control IMU, CDU pitch		0.0005	0.1148
CDUDA-pitch angle display		0.0005	0.1148
CDMCB-manual control IMU, CDU yaw		0.0005	0.1148
CDUDB-yaw angle display		0.0005	0.1148
CDUCC-manual control IMU, CDU roll		0.0005	0.1148
CDUDC-roll angle display		0.0005	0.1148

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
CDOH-optics hand controller			
PSTT-attenuator (speed controller)		0.0005	0.0000
CDOH-optics hand controller		0.0005	0.0001
CDUM-coupling display unit, IMU			
CDMOA-auto pitch assembly		0.0056	0.0441
CDMOB-auto yaw assembly		0.0056	0.0441
CDMOC-auto roll assembly		0.0056	0.0441
PSGAA-motor drive ampere and select circuit		0.0300	0.0441
PSGAB-motor drive ampere and select circuit		0.0300	0.0441
PSGAC-motor drive ampere and select circuit		0.0300	0.0441
CDUEC-encoder electronics		0.0169	0.0441
CDUED-encoder electronics		0.0169	0.0441
CDUEE-encoder electronics		0.0169	0.0441
PSCBA-binary current switch		0.0056	0.0280
PSCBB-binary current switch		0.0056	0.0280

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
PSCBC-binary current switch		0.0056	0.0280
PSALA-digital analog converter		0.0141	0.0280
PSALB-digital analog converter		0.0141	0.0280
PSALC-digital analog converter		0.0141	0.0280
CDRL-resolver load		0.3291	0.0011
CDFR-fixed resolver		0.8272	0.0011
PSMEB-5-percent 800-cps power supply		0.2424	0.0023
MBEEB-1-percent 800-cps power supply		0.2424	0.0023
PSXOB-auto ampere control 800 cps		0.3034	0.0023
PSTEB-25.6 kc power supply		0.7868	0.0429
PSXPB-25.6 kc auto ampere control		0.2345	0.0023
CDZL-zero and lock relays		0.0272	5.2930
CDZT-zero transmitter and relays		0.0281	5.2930
CDIM-inertial measuring unit controls		0.7503	0.0486
CDFI-failure indicator		0.6433	0.0462
IMFC-forward bulkhead counter		1.7111	0.1439
CDUO-coupling display unit, optics			
PSRR-resolver drive amplifier		0.0033	1.7611
PSMSA-motor drive pre-amplifier servo		0.1182	0.0728

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
PSMSB-motor drive pre-amplifier servo		0. 1182	0. 0728
SXSSA-two-speed switch		0. 0009	0. 7002
SXSSB-two-speed switch		0. 0009	0. 7002
CDUEA-encoder electronics		0. 0084	2. 3075
CDUEB-encoder electronics		0. 0084	2. 3075
PSASA-motor drive amplifier		0. 0009	0. 8680
PSASB-motor drive amplifier		0. 0009	0. 8680
PSREA-power amplifier		0. 0014	1. 1526
CDCG-cosecant generator		0. 4047	0. 2372
CDOBA-buffer circuit		0. 0[illegible]8	2. 4753
CDOBB-buffer circuit		0. 0093	2. 4753
PSALD-digital analog converter		0. 9599	2. 2355
PSALE-digital analog converter		0. 9599	2. 2355
PSXPA-auto. amplifier control, 25. 6 kc		0. 0014	1. 0663
PSTBA-power supply, 25. 6 kc		0. 0052	2. 2355
PSXOA-auto. amplifier control, 800 cps, 28 v		0. 0014	1. 1526
PSMEA-power supply, 800 cps, 5 percent, 28 v		0. 0014	1. 1526
CDRC-resistors and capacitors		0. 1332	0. 0813
CDMOD-CDU shaft assembly		0. 9524	0. 5351
CDMOE-CDU trans assembly		0. 0061	2. 4067

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
IMU-inertial measuring unit			
IMGA-gimbal assembly		4.5864	962.2317
PSIPX-a-c differential amplifier		0.1060	28.9898
PSIPY-a-c differential amplifier		0.1060	28.9898
PSIPZ-a-c differential amplifier		0.1060	28.9898
PSPIX-interrogator		0.2223	42.0864
PSIPY-interrogator		0.2223	42.0864
PSPIZ-interrogator		0.2223	42.8640
PSCSX-ternary current switch		0.3981	60.7181
PSCSY-ternary current switch		0.3981	60.7181
PSCSZ-ternary current switch		0.3981	60.7181
PSDCA- d-c differential amplifier		0.0558	19.1801
PSDCB- d-c differential amplifier		0.0558	19.1801
PSDCC-d-c differential amplifier		0.0558	19.1801
PSDCX-d-c differential amplifier		0.0558	19.1801
PSDCY-d-c differential amplifier		0.0558	19.1801
PSDCZ-d-c differential amplifier		0.0558	19.1801
PSOC-28 v dc power supply		0.0535	28.9898
PSHWA-+120 +12 v dc power supply		1.7120	9.0411
PSHWB-+120 +12 v dc power supply		1.7120	9.0411
IMLC-inertial measuring unit load compensate		0.4783	2.6497

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
PGAAX-gimbal coarse alignment amplifier		0.0741	23.2544
PGAAY-gimbal coarse alignment amplifier		0.0741	23.2544
PGAAZ-gimbal coarse alignment amplifier		0.0741	23.2544
PSGAX-gimbal servo amplifier		0.1501	34.5416
PSGAY-gimbal servo amplifier		0.1501	34.5416
PSGAZ-gimbal servo amplifier		0.1501	34.5416
PSCMX-PIPA calibration modulation		0.0192	12.3341
PSCMY-PIPA calibration modulation		0.0192	12.3341
PSCMZ-PIPA calibration modulation		0.0192	12.3341
PSGCX-gyro calibration modulation		0.0216	13.0913
PSGCY-gyro calibration modulation		0.0216	13.0913
PSGCZ-gyro calibration modulation		0.0216	13.0913
PSTS-temperature control power supply		3.3954	28.9898
PSMC-1 percent power amplifier, 3200 cps, 2 v		0.0347	8.3988
PSOA-auto. amplifier control 3200 cps		0.0347	8.3988
PSAO-temperature controller		0.3737	76.2896
IMBL-backup mode and lamps		4.2680	257.8511

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
CDMV-map and data viewer		0.0005	0.0000
CDMC-map and data viewer control		0.0005	0.0000
SCTA-scanning telescope assembly		7.1978	1.3410
SCTD-scanning telescope, hand-crank			
SCTD-SCT hand-crank		0.0005	0.0010
CDSA-SCT display of shaft angle		0.0005	0.0010
CDSD-SCT display of trunnion angle		0.0005	0.0010
SCTE-scanning telescope electronics			
PSASE-motor drive, trunnion		0.0009	0.9185
PSASF-motor drive, shaft		0.0009	0.9185
PSMSE-motor drive, pre-amplifier servo		0.0005	0.3454
PSMSF-motor drive, pre-amplifier servo		0.0005	0.3454
SCR-offset relay		0.0005	5.8375
SCZT-zero optics transformer		0.3315	0.1239
SCTM-SCT motor generator		3.8568	1.438

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
GUIDANCE AND NAVIGATION SUBSYSTEM (Cont)			
SXT			
SXTA-sextant assembly		11.5825	6.5089
PSASC-motor drive amplifier, shaft		0.3475	0.1815
PSASD-motor drive amplifier, trunnion		0.3475	0.1815
SXSSG-2-speed switch		0.0009	0.8471
PSTP-tracker power		0.0038	2.1017
SXTK-tracker		0.0263	5.5872
SXTT-isolation transformer		0.0942	0.0475
PSMSC-motor drive preamplifier servo		0.0005	0.3916
PSMSD-motor drive preamplifier servo		0.0005	0.3916
SXTR-zero optics relay		0.0370	6.6224
SXSSD-Z-speed switch		0.0009	0.8471
MIN-minimum impulse controls		0.0047	0.0978
COMMUNICATIONS AND DATA SUBSYSTEM			
PNDD-near-earth down data			
PNDL-near-earth down data amplifier limiter		0.0001	0.0000
PNDF-near-earth down data filter		0.0001	0.0000
PNDS-near-earth down data switch		0.0001	0.0000
PVUD-deep-space up-voice discriminator		0.0001	3.0980
PDUD-deep-space up-data discriminator		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
PVDD-deep-space down voice		0.0001	0.0410
PDDD-deep-space down voice			
PDDA-deep-space down-data amplifier limiter		0.0001	0.0048
PDDM-deep-space down-data pi-phase modulator		0.0001	0.0035
PDDF-deep-space down-data filter		0.0001	0.0112
PDDM-deep-space down-data modulator		0.0001	0.0005
PDDL-deep-space down-data limiter		0.0001	0.0018
PFPM-FM and PM mixing network			
PPMM-PM mixing network		0.0001	0.0001
PFMM-FM mixing network		0.0001	0.0001
PPSD-power supply		0.0053	3.0540
PEKD-emergency key		0.0001	0.0001
KEY-key		0.0001	0.0001
SPST-space suit		0.0011	0.0001
HGAD-high-gain antenna deployment mechanism			
HGSQ-HGA squib		0.0034	0.0001
HGSP-HGA springs		0.0001	0.0000
HGAB-HGA bearings		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
VRB-VHF recovery beacon		0. 0005	0. 0000
HFX-HF transceiver		0. 0050	0. 0000
HEPK-belt pack		0. 0011	0. 0001
FMX-VHF/FM transmitter			
FMPA-VHF/FM power amplifier and power supply		0. 0001	0. 0000
FMEX-VHF/FM exciter		0. 0001	0. 0000
FMCC-VHF/FM controls		0. 0001	0. 0000
ACRC-audio center receiver			
ACCUA-audio center control unit A		0. 0001	0. 0000
ACCUB-audio center control unit B		0. 0001	0. 0000
ACCUC-audio center control unit C		0. 000[illegible]	0. 0000
ACRAA-audio center receiver A		0. 0001	0. 0000
ACRAB-audio center receiver B		0. 0001	0. 0000
ACRAC-audio center receiver C		0. 0001	0. 0000
ACTM-audio center transmitter			
ACTAA-audio center transmitter A		0. 0001	0. 0000
ACTAB-audio center transmitter B		0. 0001	0. 0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
ACTAC-audio center transmitter C		0.0001	0.0000
ACCUA-audio center control unit A		0.0001	0.0000
ACCUB-audio center control unit B		0.0001	0.0000
ACCUC-audio center control unit C		0.0001	0.0000
SPA-S-band power amplifier			
SPPS-S-band power amplifier power supply		0.0001	0.0000
SPTW-S-band power amplifier traveling wave tube		0.0002	0.0001
SPSE-S-band power amplifier switching equipment		0.0001	0.0000
SPAC-S-band power amplifier communication controls		0.0001	0.0000
USB-unified S-band equipment			
USBT-unified S-band transponder		0.4010	35.4060
USBC-unified S-band controls		0.0104	0.5400
SCR-signal conditioners			
SCDAA-V signal conditioner d-c amplifiers A to V	(22)	0.0010	0.9520

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
SCPDA-phase sensory demodulator (A)		0.0001	0.0316
SCATA-signal conditioner attenuator A		0.0001	0.0531
SCATB-signal conditioner attenuator B		0.0001	0.0531
SCATC-signal conditioner attenuator C		0.0001	0.0531
SCATD-signal conditioner attenuator D		0.0001	0.0316
SCFD-frequency sensory demodulator		0.0001	0.0280
SCADA-signal conditioner a-c to d-c converter A		0.0001	0.0280
SCADB-signal conditioner a-c to d-c converter B		0.0001	0.0280
SCADC-signal conditioner a-c to d-c converter C		0.0001	0.0280
SCADD-signal conditioner a-c to d-c converter D		0.0001	0.0280
SCADE-signal conditioner a-c to d-c converter E		0.0001	0.0280
SCADF-signal conditioner a-c to d-c converter F		0.0001	0.0280
SCPS-signal conditioner power supply		0.0001	0.0736
SCCC-signal conditioner communications controls		0.0001	0.0033
PCMO-PCM oscillator		0.0001	0.2790

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
CBX-C-band transponder			
CBRA-C-band transponder receiver A		0.0001	0.0000
CBRB-C-band transponder receiver B		0.0001	0.0000
CBRC-C-band transponder receiver C		0.0001	0.0000
CBRD-C-band transponder receiver D		0.0001	0.0000
CBRM-C-band transponder less receiver and magnetron		0.0001	0.0000
CBMT-C-band transponder magnetron		0.0001	0.0000
CBCO-C-band transponder controls		0.0001	0.0000
AMI-VHF/AM transmitter, receiver			
AMIM-VHF/AM transmitter		0.1323	0.0000
AMRFA-VHF/AM receiver A, radio frequency		0.0003	0.0000
AMRFB-VHF/AM receiver B, radio frequency		0.0003	0.0000
AMIF-VHF/AM receiver intermediate frequency		0.0187	0.0000
AMAF-VHF/AM power supply and audio frequency		0.0107	0.0000
AMCC-VHF/AM communications controls		0.0027	0.0000

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
PCM-PCM telemetry			
THLGA-high-level analog gate A		0.0002	0.1204
THLGB-high-level analog gate B		0.0002	0.1204
THLGC-high-level analog gate C		0.0002	0.1204
THLGD-high-level analog gate D		0.0002	0.1204
THLGE-high-level analog gate E		0.0002	0.1204
THLGF-high-level analog gate F		0.0002	0.1204
THLGG-high-level analog gate G		0.0002	0.1204
THLGH-high-level analog gate H		0.0002	0.1204
THLGIC-high-level analog gate I		0.0002	0.1204
THLGJ-high-level analog gate J		0.0002	0.1204
TLLGA-low-level analog gate A		0.0002	0.1204
TLLGB-low-level analog gate B		0.0002	0.1204
TLLGC-low-level analog gate C		0.0002	0.1204
TLLA-low-level amplifier		0.0002	0.0931
TMADA-analog driver A		0.0001	0.0704
TMADB-analog driver B		0.0001	0.0704
THSG-high-speed gates		0.0001	0.0704
TADC-analog digital coder		0.0003	0.1715
TDMGA-digital multiplexer gate A		0.0001	0.0624
TDMGB-digital multiplexer gate B		0.0001	0.0624

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
TDMGC-digital multiplexer gate C		0.0001	0.0624
TDMGD-digital multiplexer gate D		0.0001	0.0624
TDMGE-digital multiplexer gate E		0.0001	0.0624
TDMGF-digital multiplexer gate F		0.0001	0.0624
TMOR-output register and drivers		0.0002	0.1201
TSSF-synch select and format identification		0.0001	0.0083
TDTD-data transfer drive		0.0001	0.0768
TAPG-programmer module #1		0.0001	0.0931
TBPG-programmer module #2		0.0001	0.0931
TCPG-programmer module #3		0.0001	0.0931
TDPG-programmer module #4		0.0001	0.0931
TMPS-power supply		0.0001	0.0712
TMCH-chassis		0.0001	0.0082
MCFN-microphone and mike amplifier			
MFMKA-microphone A		0.0001	0.0000
MFMKB-microphone B		0.0001	0.0000
MFMKC-microphone C		0.0001	0.0000
MFMKD-microphone D		0.0001	0.0000
MFMKE-microphone E		0.0001	0.0000
MFMKF-microphone F		0.0001	0.0000
MFAPA-amplifier A		0.0001	0.0000
MFAPB-amplifier B		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
COMMUNICATIONS AND DATA SUBSYSTEM (Cont)			
MFAPC-amplifier C		0.0001	0.0000
MFAPD-amplifier D		0.0001	0.0000
MFAPE-amplifier E		0.0001	0.0000
MFAPF-amplifier F		0.0001	0.0000
MFAMA-microphone and amplifier assembly A		0.0001	0.0000
MFAMB-microphone and amplifier assembly B		0.0001	0.0000
MFAMC-microphone and amplifier assembly C		0.0001	0.0000
MFAMD-microphone and amplifier assembly D		0.0001	0.0000
MFAME-microphone and amplifier assembly E		0.0001	0.0000
MFAMF-microphone and amplifier assembly F		0.0001	0.0000
MHCTA-connector A		0.0001	0.0000
MHCTB-connector B		0.0001	0.0000
MHCTC-connector C		0.0001	0.0000
HDST-headset			
HSEPA-earphone A		0.0001	0.0000
HSEPB-earphone B		0.0001	0.0000
HSEPC-earphone C		0.0001	0.0000
HSEPD-earphone D		0.0001	0.0000
HSEPE-earphone E		0.0001	0.0000
HSEPF-earphone F		0.0001	0.0000
HHCTA-connector A		0.0001	0.0000
HHCTB-connector B		0.0001	0.0000
HHCTC-connector C		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
INSTRUMENTATION SUBSYSTEM			
CBA-beacon (C-band) antenna		0.0001	0.0000
CTEK-central timing equipment			
CTPSA-power supply		0.0002	0.0000
CTPSE-power supply		0.0002	0.0000
CTIO-internal oscillator network		0.0001	0.0000
CTFAA-frequency divider and delay		0.0001	0.0000
CTFAB-frequency divider and delay		0.0001	0.0000
CTFAC-frequency divider and delay		0.0001	0.0000
CTCFA-comparator		0.0001	0.0000
CTAFA-amplifier		0.0001	0.0000
CTRE-12-kc reset		0.0001	0.0000
CTBFB-512 kc buffer		0.0001	0.0000
CTFBA-frequency divider and reset		0.0001	0.0000
CTFBB-frequency divider and reset		0.0001	0.0000
CTFBC-frequency divider and reset		0.0001	0.0000
CTCFB-comparator		0.0001	0.0000
CTFDA-frequency divider and reset		0.0001	0.0000
CTFDB-frequency divider and reset		0.0001	0.0000
CTFDC-frequency divider and reset		0.0001	0.0000
CTCF-comparator		0.0001	0.0000
CTAFD-amplifier		0.0001	0.0000
CTFEA-frequency divider and reset		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
INSTRUMENTATION SUBSYSTEM (Cont)			
CTFEB-frequency divider and reset		0.0001	0.0000
CTFEC-frequency divider and reset		0.0001	0.0000
CTCFE-comparator		0.0001	0.0000
CTAFE-amplifier		0.0001	0.0000
CTFFA-frequency divider and reset		0.0001	0.0000
CTFFB-frequency divider and reset		0.0001	0.0000
CTFFC-frequency divider and reset		0.0001	0.0000
CTCFF-comparator		0.0001	0.0000
CTAFF-amplifier		0.0001	0.0000
CTFGA-frequency divider and reset		0.0001	0.0000
CTFGB-frequency divider and reset		0.0001	0.0000
CTFGC-frequency divider and reset		0.0001	0.0000
CTCFG-comparator		0.0001	0.0000
CTAFG-amplifier		0.0001	0.0000
CTFHA-frequency divider and reset		0.0001	0.0000
CTFHB-frequency divider and reset		0.0001	0.0000
CTFHC-frequency divider and reset		0.0001	0.0000
CTCFH-comparator		0.0001	0.0000
CTAFH-amplifier		0.0001	0.0000
CTFIA-frequency divider and reset		0.0001	0.0000
CTFIB-frequency divider and reset		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
INSTRUMENTATION SUBSYSTEM (Cont)			
CTFIC-frequency divider and reset		0.0001	0.0000
CTCFI-comparator		0.0001	0.0000
CTAFI-amplifier		0.0001	0.0000
CTFJA-frequency divider and reset		0.0001	0.0000
CTFJB-frequency divider and reset		0.0001	0.0000
CTFJC-frequency divider and reset		0.0001	0.0000
CTGFJ-comparator		0.0001	0.0000
CTAFJ-amplifier		0.0001	0.0000
CTBFH-buffer		0.0001	0.0000
CTHFB-amplifier		0.0001	0.0000
EMD-entry monitor display			
EMDA-EMD accelerometers		0.0001	0.0000
EMDG-EMD gyro		0.0001	0.0000
EMRG-EMO rate gyro		0.0001	0.0000
EMSM-EMD stepper motor		0.0001	0.0000
EMPI-EMD power inverter		0.0001	0.0000
EMCV-EMD corridor verification indicator		0.0001	0.0000
EMSA-EMD servo amplifier		0.0001	0.0000
EMTI-EMD threshold initiation module		0.0001	0.0000
EMTD-EMD time delay		0.0001	0.0000
EMSD-EMD stepper motor drive		0.0001	0.0000
EMME-EMD miscellaneous electronics		0.0001	0.0000

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Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
INSTRUMENTATION SUBSYSTEM (Cont)			
HGAG-high-gain antenna			
HGRE-radiating elements		0.0001	0.0000
HGPD-power dividers		0.0100	0.0001
HGBS-beam switch		0.0001	0.0000
HGDM-drive motor		0.0061	0.0000
HGGH-gimbal and harmonic drive		0.0210	0.0001
HGAS-synchro		0.0009	0.0000
HGSA-servo amplifier		0.0009	0.0000
HGMS-sensor and motor		0.0061	0.0000
HGTR-slip rings and transmission lines		0.0091	0.0001
SEN-sensor			
SEN-sensor		0.0001	0.0000
UDL-up-data link			
UDLR-receiver		0.0004	0.0000
UDLD-decoder		0.0001	0.0000
UDLS-switching matrix		0.0002	0.0000
UDLP-power supply		0.0003	0.0000
DSC VHF-2 Kmc omni-antenna			
OMNIA-VHF FMC omni-antenna A		0.0001	0.0001
OMNIB-VHF FMC omni-antenna B		0.0001	0.0001
GMT-Greenwich mean time assembly			

[redacted]

[redacted]

Table 1-3. Preliminary Apollo Subsystems Component Criticalities and Sensor Rankings (Cont)

Component	Quantity	Criticality (Failures per 10^6 missions)	Sensor Ranking (Increase in crew safety reliability per 10^6 missions)
INSTRUMENTATION SUBSYSTEM (Cont)			
GMT-Greenwich mean time assembly		0.0001	0.0000
RBA-recovery antenna			
RBAS-RBA squib		0.0001	0.0001
RBAA-RBA-HF and VHF antenna		0.0057	0.0076
RBAD-RBA-diplexer		0.0014	0.0019
ARA- auxiliary recovery antenna			
ARA-auxiliary recovery antenna		0.0072	0.0000

[redacted]

[redacted]

LEM INTEGRATION

SUMMARY

Studies have been conducted to evaluate the generalized elliptic transfer orbits between LEM and CM/SM lunar parking orbits, the parameters associated with the terminal homing rendezvous maneuver, and the docking requirements for crew safety and mission success. The contemplated trajectories of the CM/SM were evaluated as well as the performance requirements required for backup capability and recovery of the LEM by the CM/SM in the event of LEM failure. An introductory study was conducted to determine currently anticipated miss distances for the LEM at the insertion point of the terminal rendezvous maneuver. Analyses were conducted to provide additional LEM guidance and control methods involving on-board spacecraft equipment which could be used to increase the reliability of LEM rendezvous.

ANALYSIS

Time requirements and restrictions associated with LEM operations were incorporated in the 14-day maximum mission time profile. Time restrictions were established according to the present 5-day limit on LEM use. At present there are no provisions for the extension of LEM capability by means of lunar-based supplies; however, such provisions may be made as more definite data are obtained concerning the availability of lunar based support.

Preliminary reliability logic diagrams illustrating mission success for the LEM launch, navigational sighting and acquisition, thrust vector alignment, ΔV firing and terminal rendezvous phases of LEM operations are given in Figures 1-3 to 1-7.

The GAEC Design Control Specification, LSP-370-2, "Navigation and Guidance Subsystem Rendezvous Radar/Transponder and Landing Radar Sections," was reviewed and evaluated for the purpose of assuring compatibility between GAEC requirements and overall spacecraft requirements. Comments on the specification were submitted to GAEC. Incorporation of the following items was suggested:

1. A failure reporting system
2. Applicable reference documents
3. Delivery and approval procedures for tests and reports.

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PLANNED ACTIVITIES

The following are planned activities for the next quarter:

1. Review of GAEC LEM reliability logic diagrams to determine interrelations with CM-SM reliability logic.

2. Studies in determining CM SM backup capabilities for LEM recovery.

3. Review of contemplated mission paths analysis of LEM guidance and navigation time reliability functions.

4. Evaluation of proposed models under development by GAEC concerning LEM reliability versus weight trade-off studies.

5. Action establishing GAEC and S&ID reliability interface control documents, and interface revision notices.

6. Studies to evaluate guidance and navigation interfaces between MIT subsystems and GAEC subsystems in the area of reliability and interchangeability.

7. Coordination between S&ID and GAEC on LEM reliability test programs and documentation.

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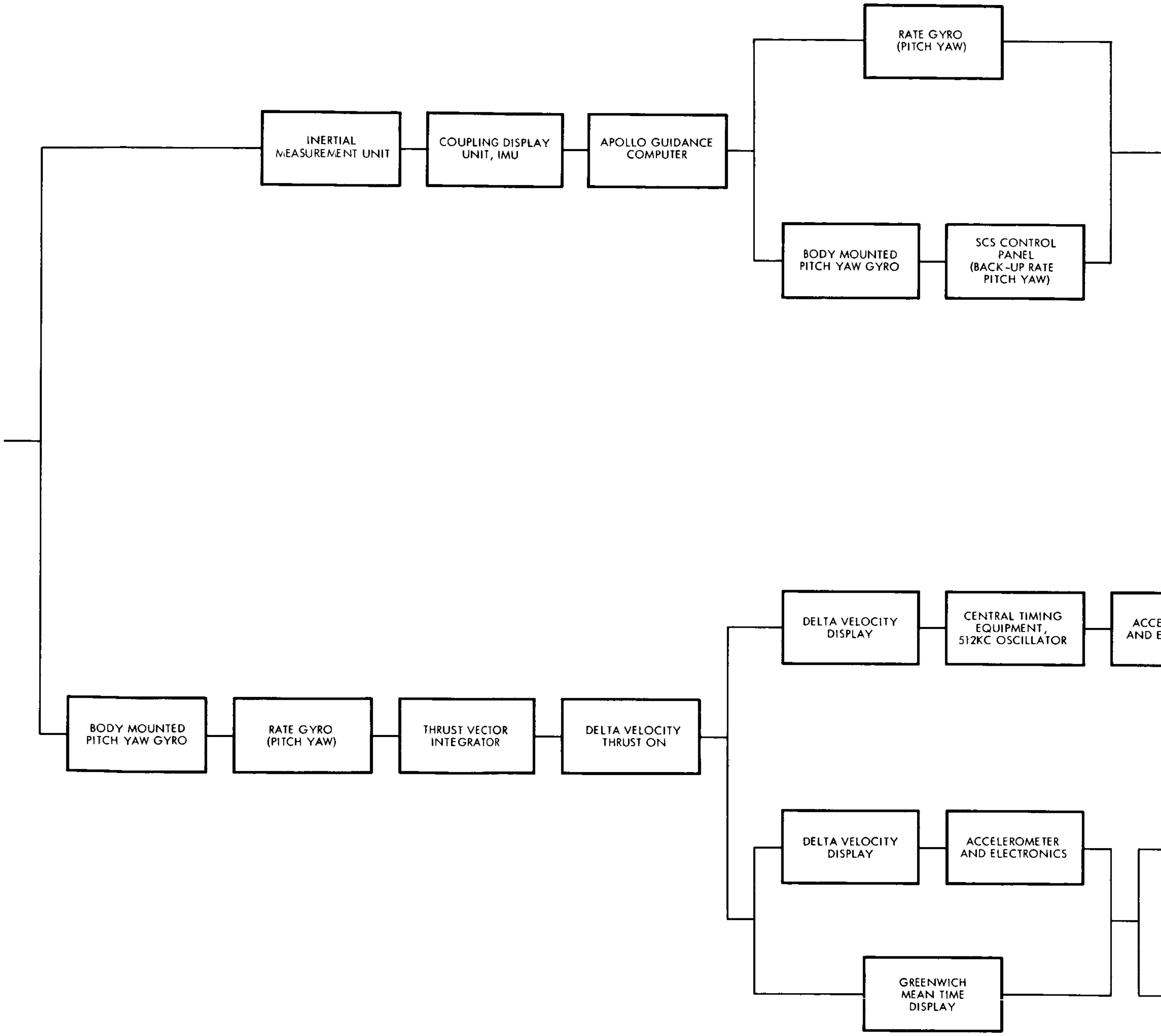
RATE GYRO (PITCH YAW)
INERTIAL MEASUREMENT UNIT
COUPLING DISPLAY UNIT, IMU
APOLLO GUIDANCE COMPUTER
BODY MOUNTED PITCH YAW GYRO
SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
DELTA VELOCITY DISPLAY
CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
BODY MOUNTED PITCH YAW GYRO
RATE GYRO (PITCH YAW)
THRUST VECTOR INTEGRATOR
DELTA VELOCITY THRUST ON
DELTA VELOCITY DISPLAY
ACCELEROMETER AND ELECTRONICS
GREENWICH MEAN TIME DISPLAY

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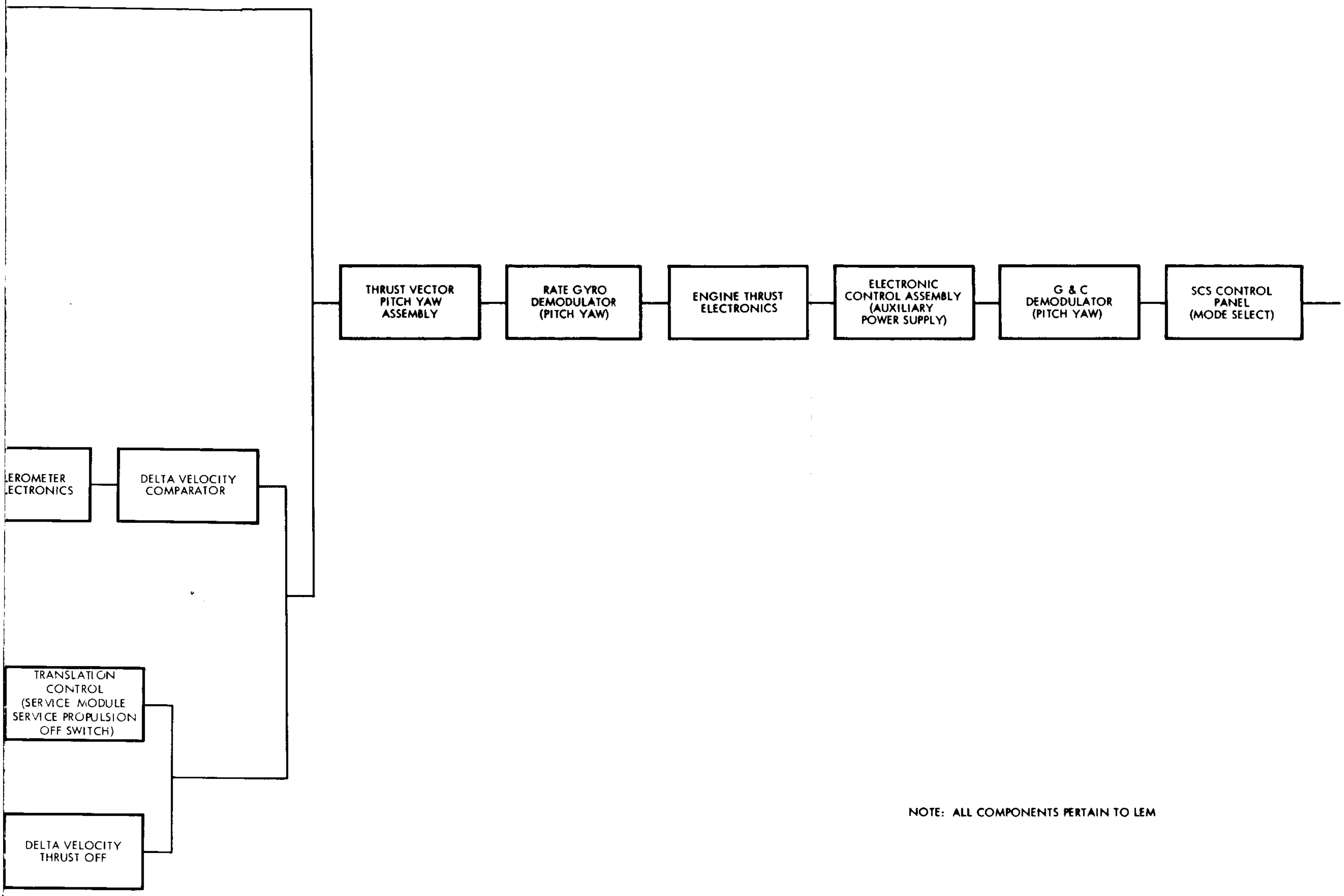

NOTE: ALL COMPONENTS PERTAIN TO LEM

Figure 1-3. LEM Launch to 50,000 Feet

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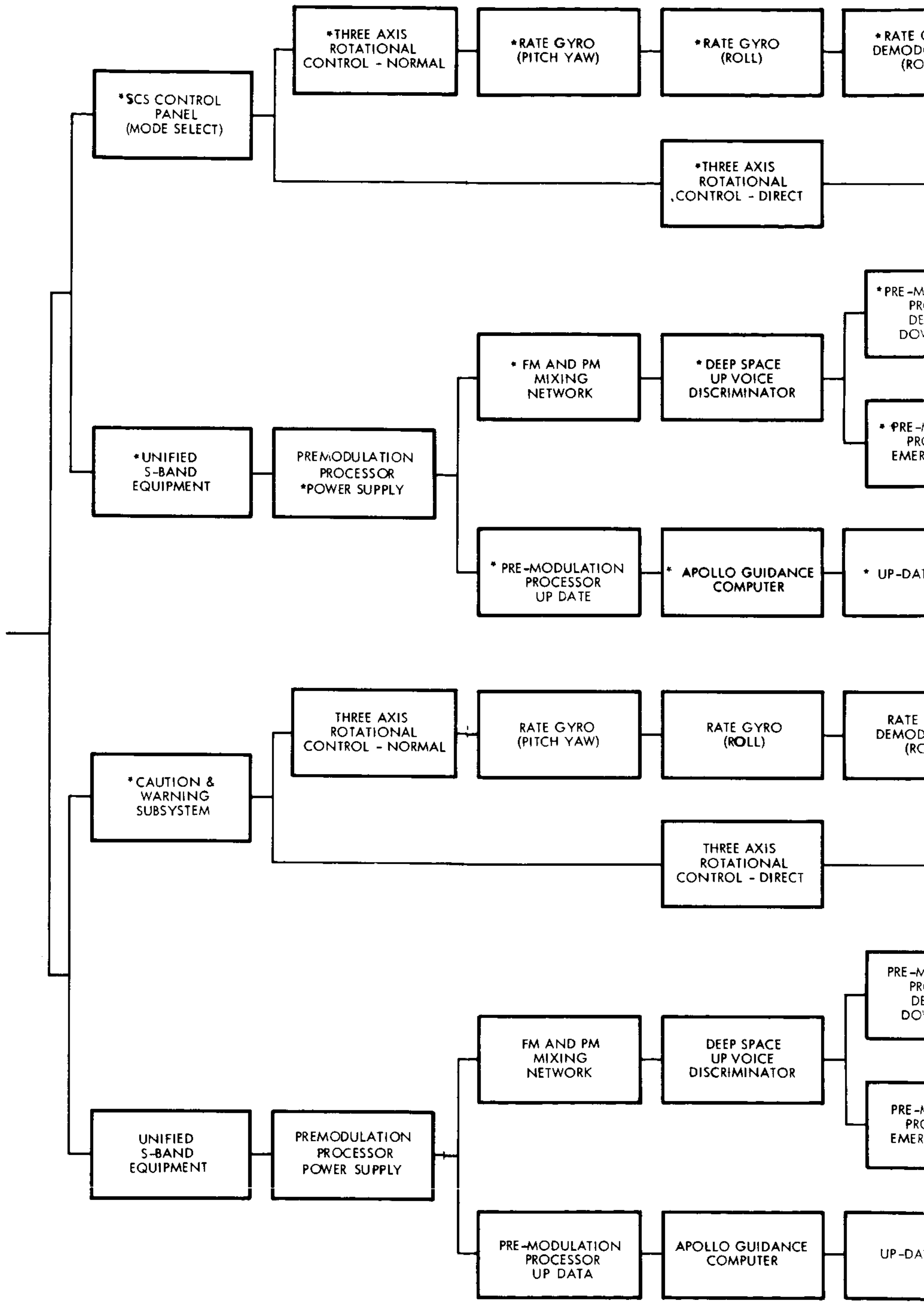
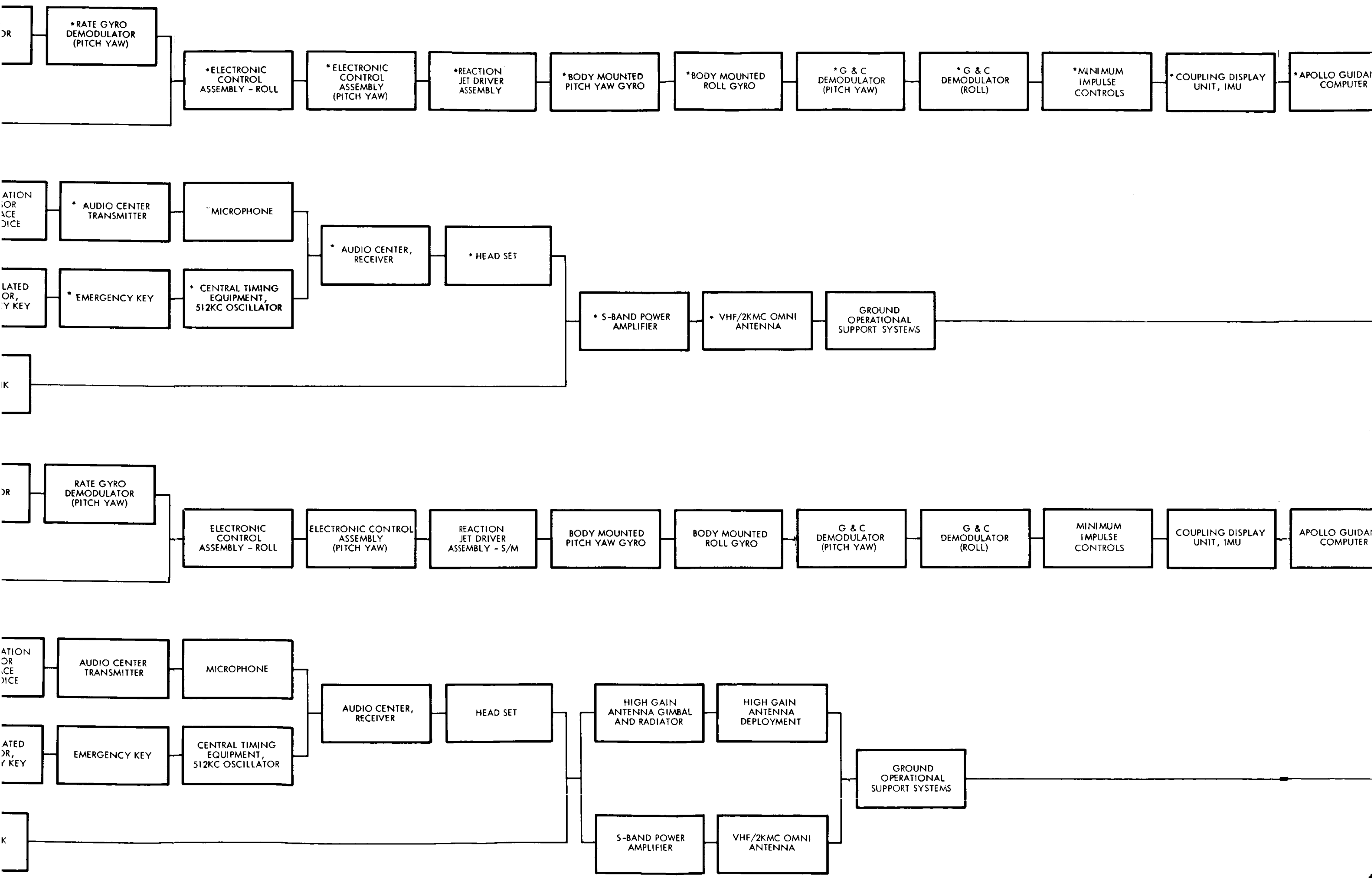
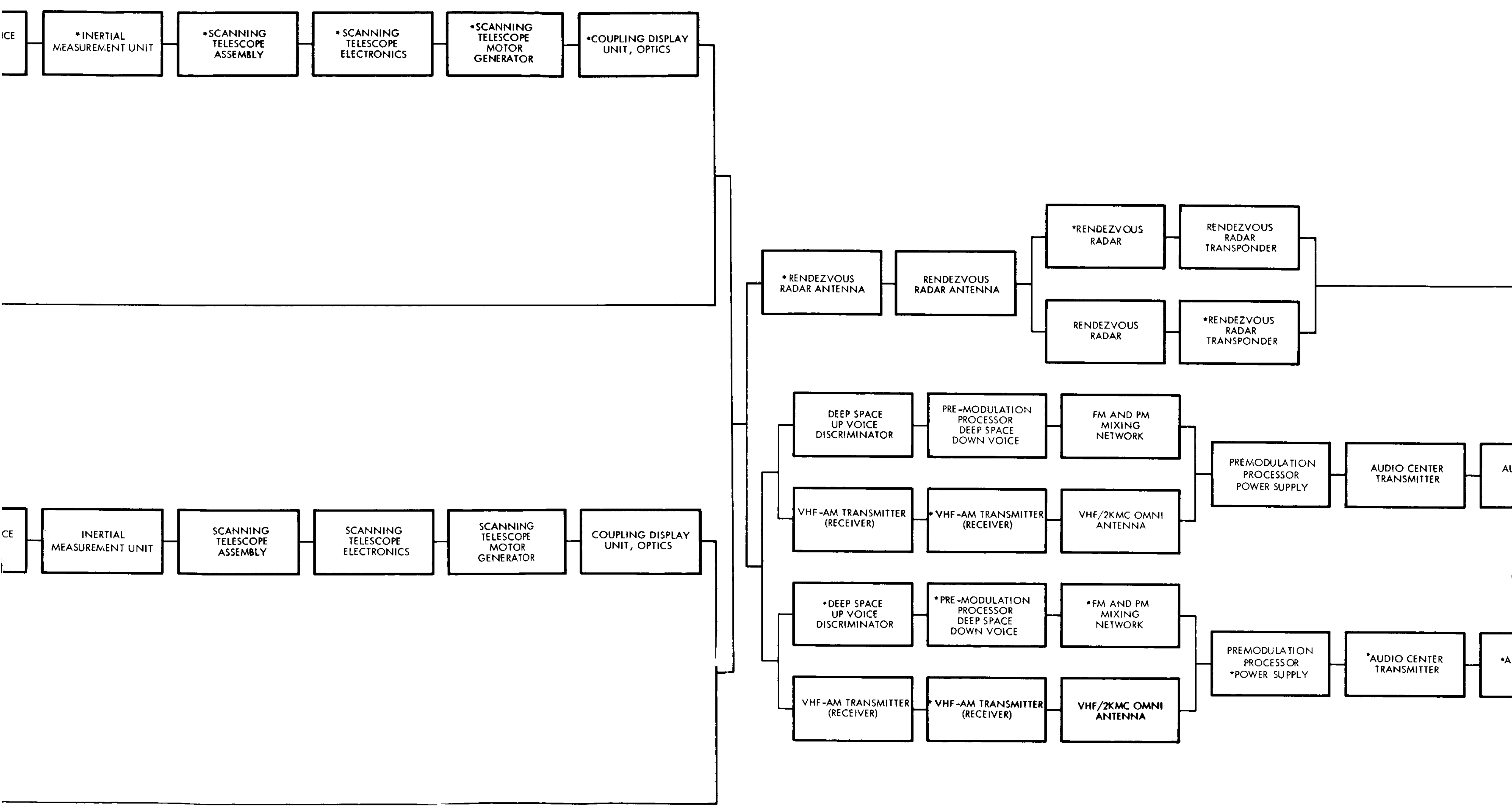


*SCS CONTROL PANEL (MODE SELECT)
*THREE AXIS ROTATIONAL CONTROL - NORMAL
*RATE GYRO (PITCH YAW)
*RATE GYRO (ROLL)
*THREE AXIS ROTATIONAL CONTROL - DIRECT
*UNIFIED S-BAND EQUIPMENT
PREMODULATION PROCESSOR *POWER SUPPLY
* FM AND PM MIXING NETWORK
* DEEP SPACE UP VOICE DISCRIMINATOR
* PRE-MODULATION PROCESSOR UP DATE
* APOLLO GUIDANCE COMPUTER
*CAUTION & WARNING SUBSYSTEM
THREE AXIS ROTATIONAL CONTROL - NORMAL
RATE GYRO (PITCH YAW)
RATE GYRO (ROLL)
THREE AXIS ROTATIONAL CONTROL - DIRECT
UNIFIED S-BAND EQUIPMENT
PREMODULATION PROCESSOR POWER SUPPLY
FM AND PM MIXING NETWORK
DEEP SPACE UP VOICE DISCRIMINATOR
PRE-MODULATION PROCESSOR UP DATA
APOLLO GUIDANCE COMPUTER



OR
*RATE GYRO DEMODULATOR (PITCH YAW)
*ELECTRONIC CONTROL ASSEMBLY - ROLL
*ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
*REACTION JET DRIVER ASSEMBLY
*BODY MOUNTED PITCH YAW GYRO
*BODY MOUNTED ROLL GYRO
*G & C DEMODULATOR (PITCH YAW)
*G & C DEMODULATOR (ROLL)
*MINIMUM IMPULSE CONTROLS
*COUPLING DISPLAY UNIT, IMU
*APOLLO GUIDAN COMPUTER
ATION OR ACE DICE
* AUDIO CENTER TRANSMITTER
MICROPHONE
* AUDIO CENTER, RECEIVER
* HEAD SET
LATED OR, Y KEY
* EMERGENCY KEY
* CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
* S-BAND POWER AMPLIFIER
* VHF/2KMC OMNI ANTENNA
GROUND OPERATIONAL SUPPORT SYSTEMS
IK
OR
RATE GYRO DEMODULATOR (PITCH YAW)
ELECTRONIC CONTROL ASSEMBLY - ROLL
ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
REACTION JET DRIVER ASSEMBLY - S/M
BODY MOUNTED PITCH YAW GYRO
BODY MOUNTED ROLL GYRO
G & C DEMODULATOR (PITCH YAW)
G & C DEMODULATOR (ROLL)
MINIMUM IMPULSE CONTROLS
COUPLING DISPLAY UNIT, IMU
APOLLO GUIDAN COMPUTER
ATION OR ACE DICE
AUDIO CENTER TRANSMITTER
MICROPHONE
AUDIO CENTER, RECEIVER
HEAD SET
HIGH GAIN ANTENNA GIMBAL AND RADIATOR
HIGH GAIN ANTENNA DEPLOYMENT
ATED OR, Y KEY
EMERGENCY KEY
CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
GROUND OPERATIONAL SUPPORT SYSTEMS
K
S-BAND POWER AMPLIFIER
VHF/2KMC OMNI ANTENNA


ICE
*INERTIAL MEASUREMENT UNIT
*SCANNING TELESCOPE ASSEMBLY
*SCANNING TELESCOPE ELECTRONICS
*SCANNING TELESCOPE MOTOR GENERATOR
*COUPLING DISPLAY UNIT, OPTICS
*RENDEZVOUS RADAR ANTENNA
RENDEZVOUS RADAR ANTENNA
*RENDEZVOUS RADAR
RENDEZVOUS RADAR TRANSPONDER
RENDEZVOUS RADAR
*RENDEZVOUS RADAR TRANSPONDER
DEEP SPACE UP VOICE DISCRIMINATOR
PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
FM AND PM MIXING NETWORK
VHF-AM TRANSMITTER (RECEIVER)
*VHF-AM TRANSMITTER (RECEIVER)
VHF/2KMC OMNI ANTENNA
PREMODULATION PROCESSOR POWER SUPPLY
AUDIO CENTER TRANSMITTER
AU
CE
INERTIAL MEASUREMENT UNIT
SCANNING TELESCOPE ASSEMBLY
SCANNING TELESCOPE ELECTRONICS
SCANNING TELESCOPE MOTOR GENERATOR
COUPLING DISPLAY UNIT, OPTICS
*DEEP SPACE UP VOICE DISCRIMINATOR
*PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
*FM AND PM MIXING NETWORK
VHF-AM TRANSMITTER (RECEIVER)
*VHF-AM TRANSMITTER (RECEIVER)
VHF/2KMC OMNI ANTENNA
PREMODULATION PROCESSOR *POWER SUPPLY
*AUDIO CENTER TRANSMITTER
*A

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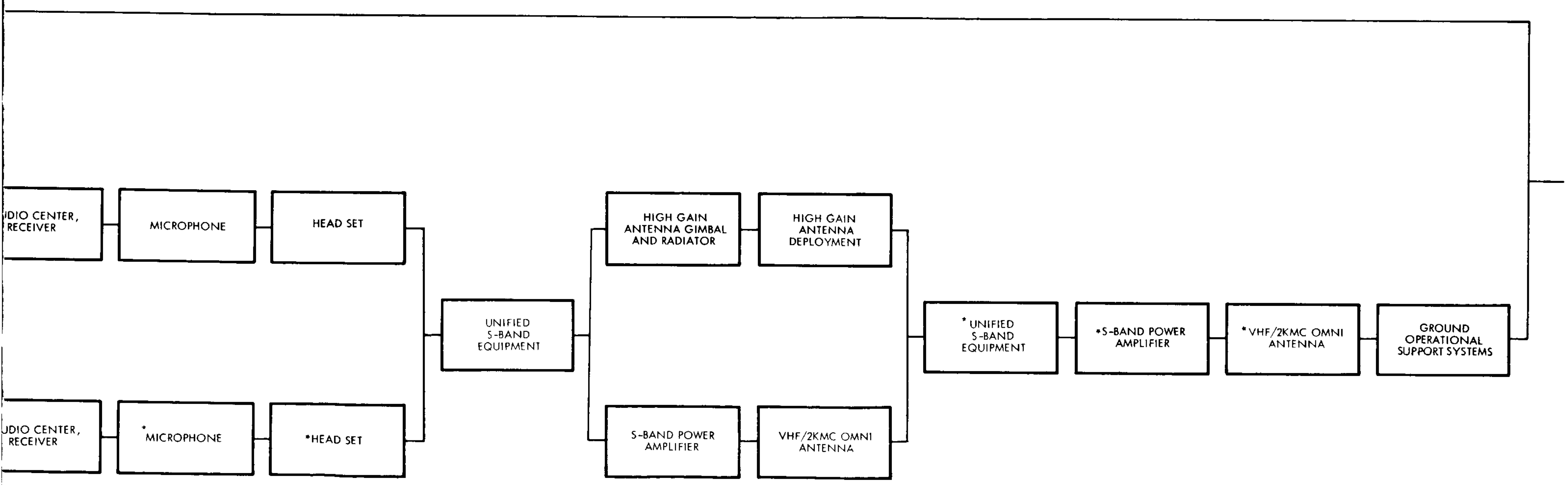
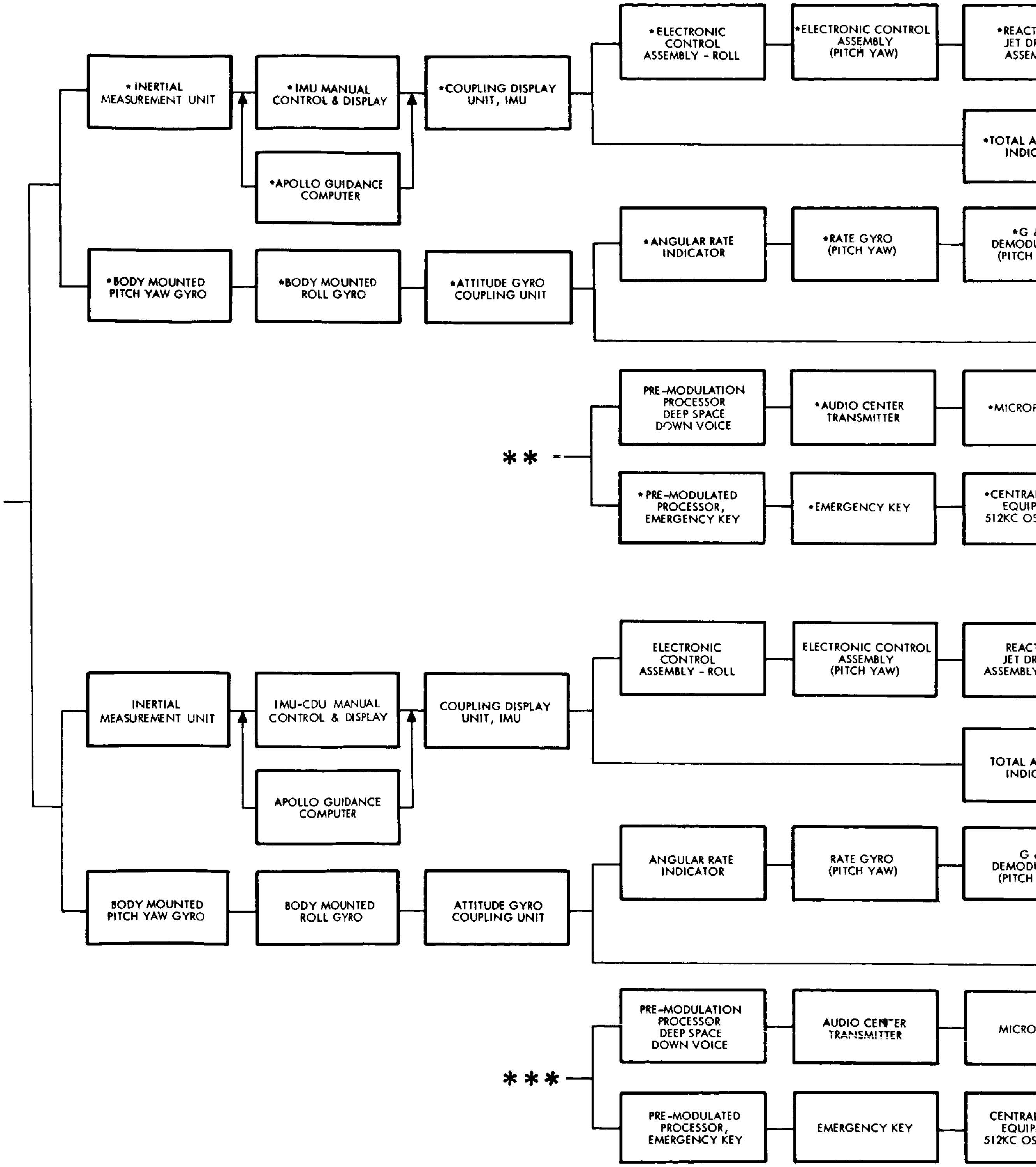
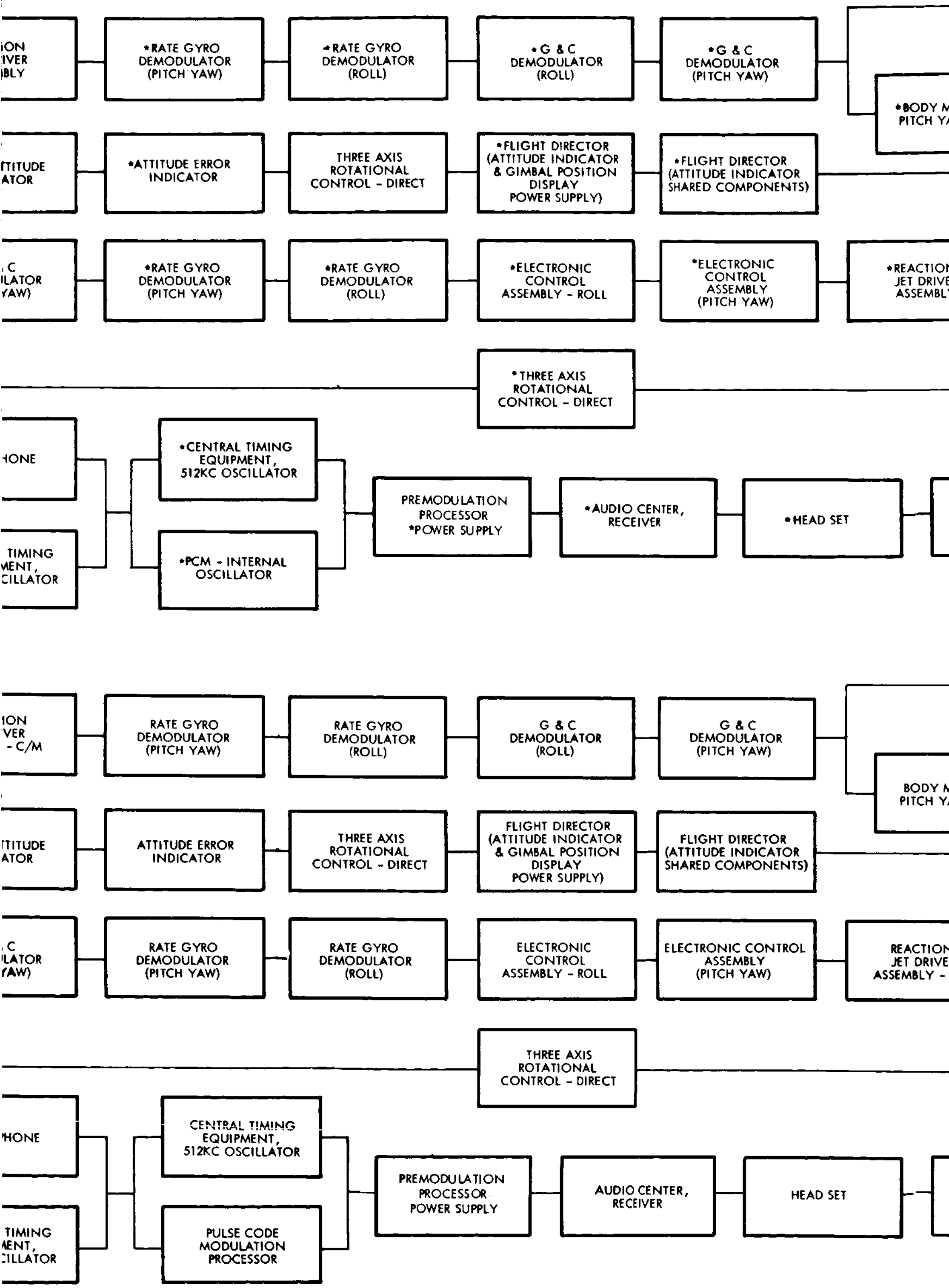
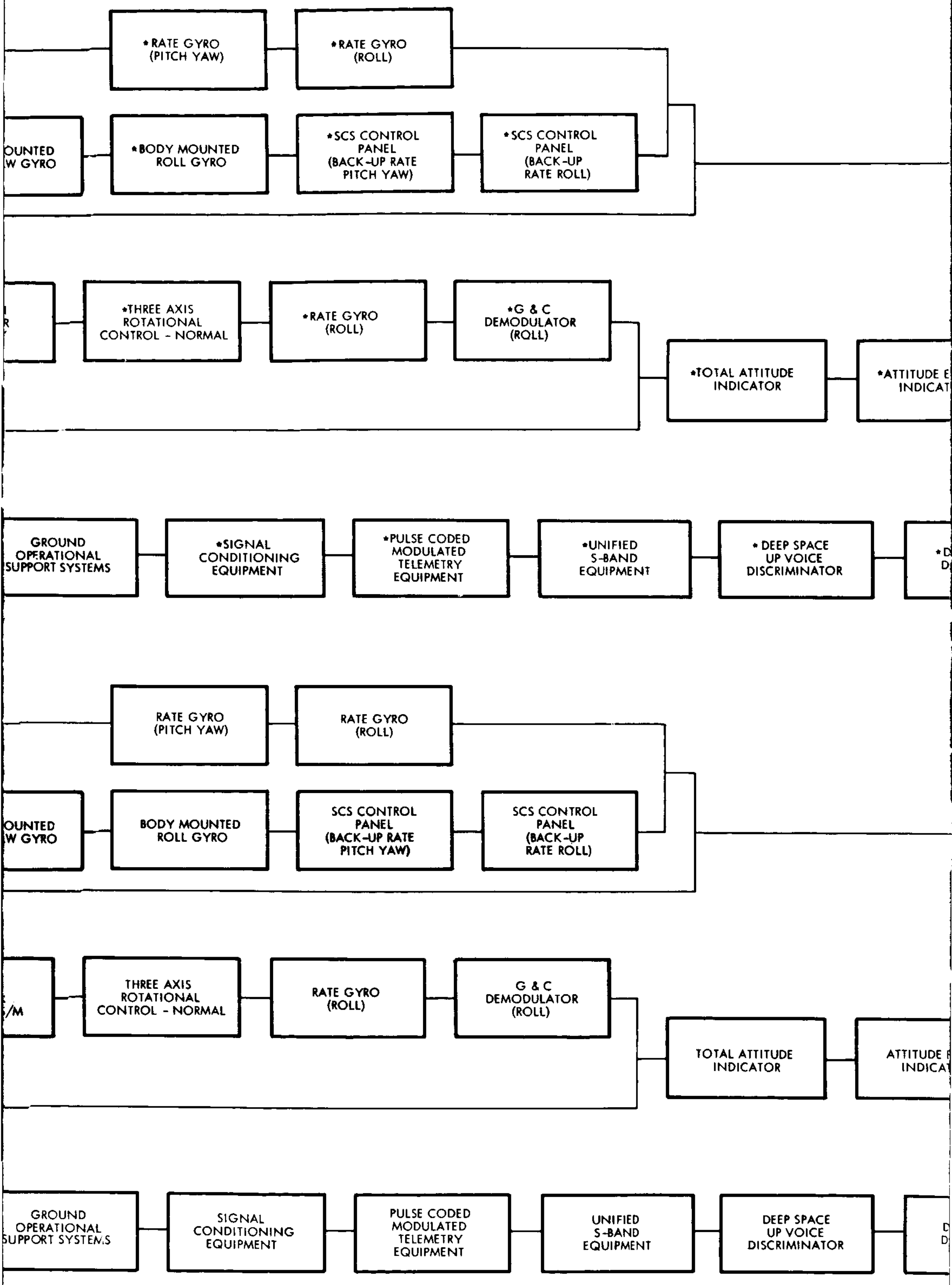


*COMPONENTS PERTAIN TO THE LEM ONLY

Figure 1-4. Navigational Sighting and LEM Acquisition


*INERTIAL MEASUREMENT UNIT
*IMU MANUAL CONTROL & DISPLAY
*COUPLING DISPLAY UNIT, IMU
*APOLLO GUIDANCE COMPUTER
*ELECTRONIC CONTROL ASSEMBLY - ROLL
*ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
*REACT JET DR ASSEM
*TOTAL A INDIC
*BODY MOUNTED PITCH YAW GYRO
*BODY MOUNTED ROLL GYRO
*ATTITUDE GYRO COUPLING UNIT
*ANGULAR RATE INDICATOR
*RATE GYRO (PITCH YAW)
*G DEMODU (PITCH
PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
*AUDIO CENTER TRANSMITTER
*MICRO
**
*PRE-MODULATED PROCESSOR, EMERGENCY KEY
*EMERGENCY KEY
*CENTRAL EQUIP 512KC OS
INERTIAL MEASUREMENT UNIT
IMU-CDU MANUAL CONTROL & DISPLAY
COUPLING DISPLAY UNIT, IMU
APOLLO GUIDANCE COMPUTER
ELECTRONIC CONTROL ASSEMBLY - ROLL
ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
REACT JET DR ASSEMBLY
TOTAL A INDIC
BODY MOUNTED PITCH YAW GYRO
BODY MOUNTED ROLL GYRO
ATTITUDE GYRO COUPLING UNIT
ANGULAR RATE INDICATOR
RATE GYRO (PITCH YAW)
G DEMODU (PITCH
PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
AUDIO CENTER TRANSMITTER
MICRO
***
PRE-MODULATED PROCESSOR, EMERGENCY KEY
EMERGENCY KEY
CENTRAL EQUIP 512KC OS


*RATE GYRO DEMODULATOR (PITCH YAW)
*RATE GYRO DEMODULATOR (ROLL)
*G & C DEMODULATOR (ROLL)
*G & C DEMODULATOR (PITCH YAW)
*ATTITUDE ERROR INDICATOR
THREE AXIS ROTATIONAL CONTROL - DIRECT
*FLIGHT DIRECTOR (ATTITUDE INDICATOR & GIMBAL POSITION DISPLAY POWER SUPPLY)
*FLIGHT DIRECTOR (ATTITUDE INDICATOR SHARED COMPONENTS)
*RATE GYRO DEMODULATOR (PITCH YAW)
*RATE GYRO DEMODULATOR (ROLL)
*ELECTRONIC CONTROL ASSEMBLY - ROLL
*ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
*THREE AXIS ROTATIONAL CONTROL - DIRECT
*CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
*PCM - INTERNAL OSCILLATOR
PREMODULATION PROCESSOR *POWER SUPPLY
*AUDIO CENTER, RECEIVER
*HEAD SET
RATE GYRO DEMODULATOR (PITCH YAW)
RATE GYRO DEMODULATOR (ROLL)
G & C DEMODULATOR (ROLL)
G & C DEMODULATOR (PITCH YAW)
ATTITUDE ERROR INDICATOR
THREE AXIS ROTATIONAL CONTROL - DIRECT
FLIGHT DIRECTOR (ATTITUDE INDICATOR & GIMBAL POSITION DISPLAY POWER SUPPLY)
FLIGHT DIRECTOR (ATTITUDE INDICATOR SHARED COMPONENTS)
RATE GYRO DEMODULATOR (PITCH YAW)
RATE GYRO DEMODULATOR (ROLL)
ELECTRONIC CONTROL ASSEMBLY - ROLL
ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
THREE AXIS ROTATIONAL CONTROL - DIRECT
CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
PULSE CODE MODULATION PROCESSOR
PREMODULATION PROCESSOR POWER SUPPLY
AUDIO CENTER, RECEIVER
HEAD SET



*RATE GYRO (PITCH YAW)
*RATE GYRO (ROLL)
OUNTED W GYRO
*BODY MOUNTED ROLL GYRO
*SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
*SCS CONTROL PANEL (BACK-UP RATE ROLL)
*THREE AXIS ROTATIONAL CONTROL - NORMAL
*RATE GYRO (ROLL)
*G & C DEMODULATOR (ROLL)
*TOTAL ATTITUDE INDICATOR
*ATTITUDE E INDICAT
GROUND OPERATIONAL SUPPORT SYSTEMS
*SIGNAL CONDITIONING EQUIPMENT
*PULSE CODED MODULATED TELEMETRY EQUIPMENT
*UNIFIED S-BAND EQUIPMENT
* DEEP SPACE UP VOICE DISCRIMINATOR
RATE GYRO (PITCH YAW)
RATE GYRO (ROLL)
OUNTED W GYRO
BODY MOUNTED ROLL GYRO
SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
SCS CONTROL PANEL (BACK-UP RATE ROLL)
/M
THREE AXIS ROTATIONAL CONTROL - NORMAL
RATE GYRO (ROLL)
G & C DEMODULATOR (ROLL)
TOTAL ATTITUDE INDICATOR
ATTITUDE INDICAT
GROUND OPERATIONAL SUPPORT SYSTEMS
SIGNAL CONDITIONING EQUIPMENT
PULSE CODED MODULATED TELEMETRY EQUIPMENT
UNIFIED S-BAND EQUIPMENT
DEEP SPACE UP VOICE DISCRIMINATOR

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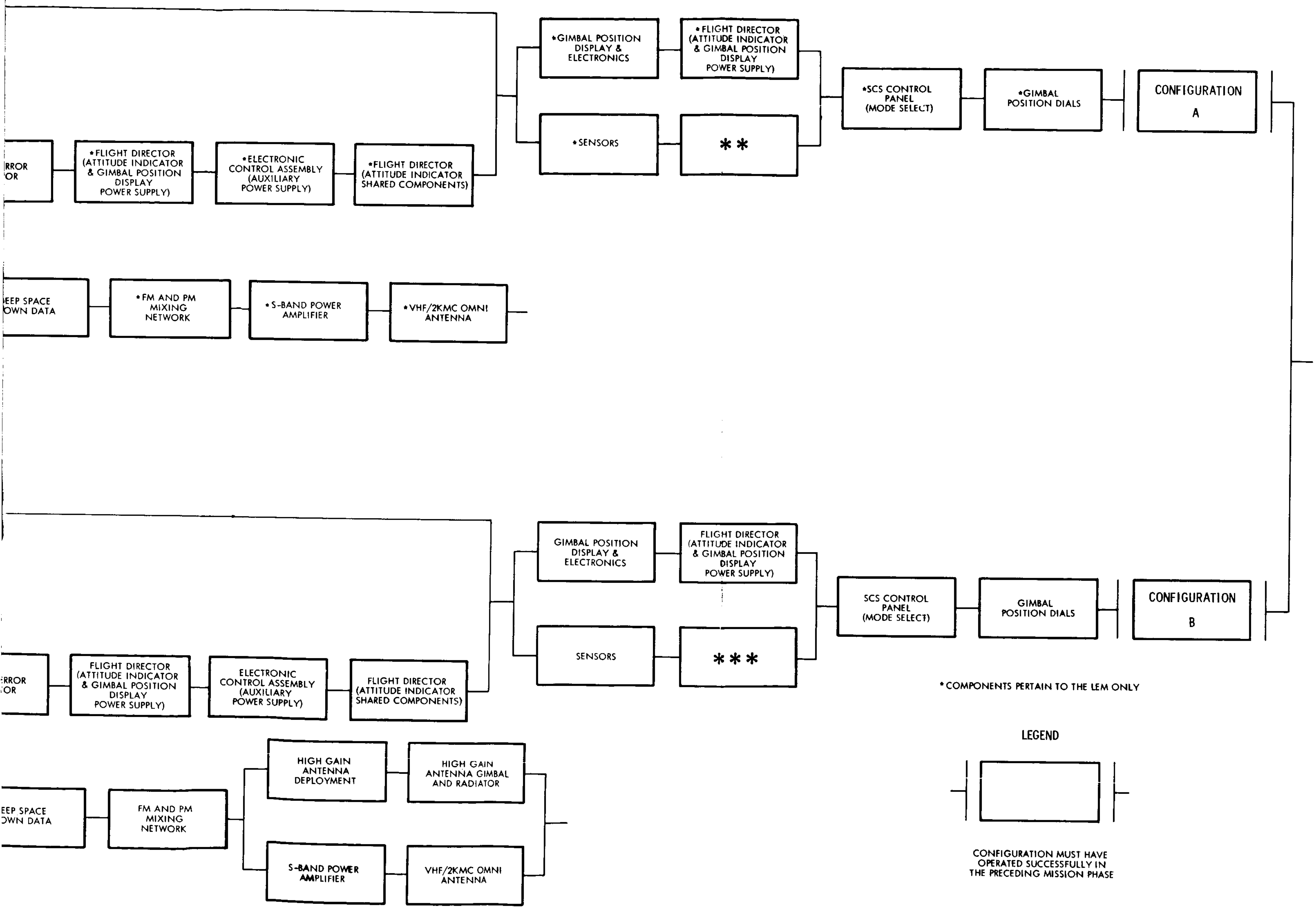

Figure 1-5. Thrust Vector Alignment (Sheet 1 of 2)

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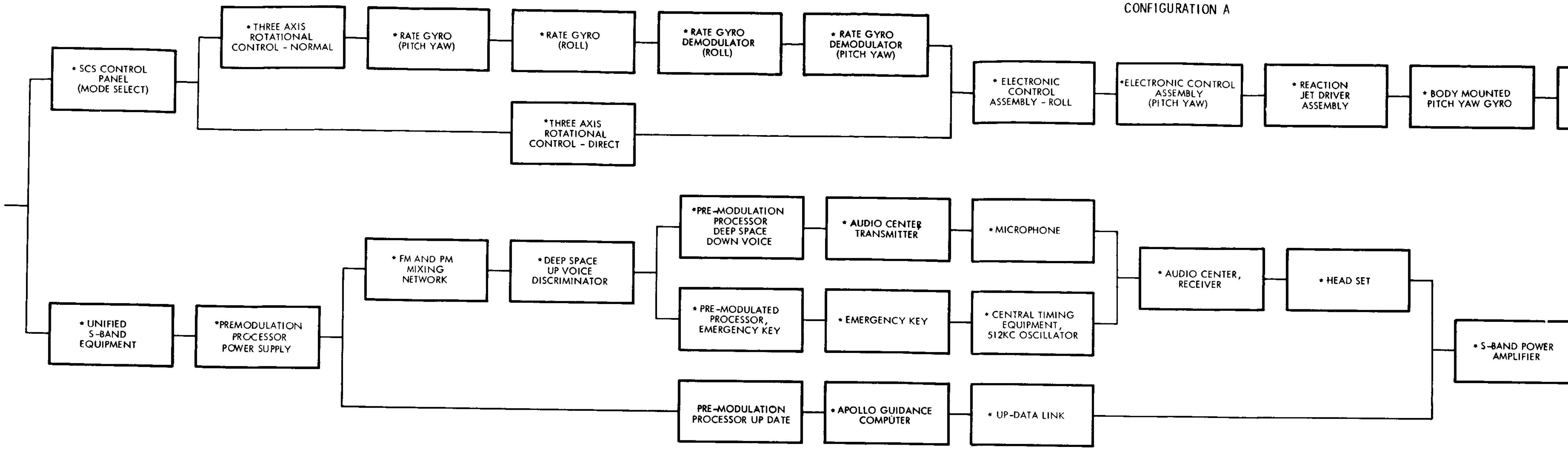
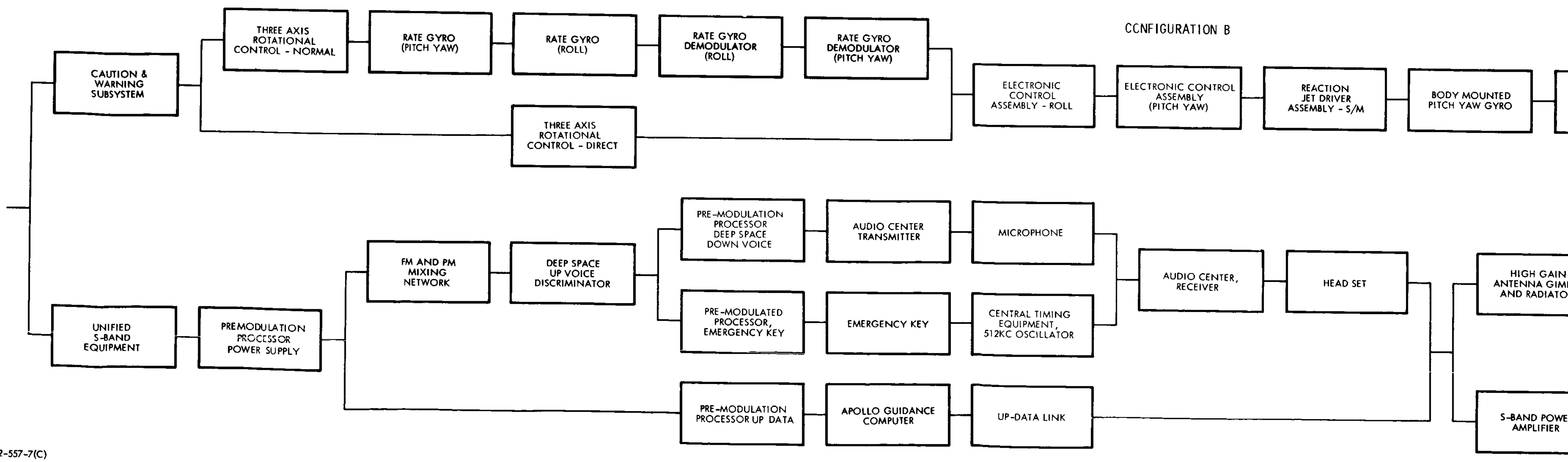

CONFIGURATION A
• SCS CONTROL PANEL (MODE SELECT)
• THREE AXIS ROTATIONAL CONTROL - NORMAL
• RATE GYRO (PITCH YAW)
• RATE GYRO (ROLL)
• RATE GYRO DEMODULATOR (ROLL)
• RATE GYRO DEMODULATOR (PITCH YAW)
• THREE AXIS ROTATIONAL CONTROL - DIRECT
• ELECTRONIC CONTROL ASSEMBLY - ROLL
• ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
• REACTION JET DRIVER ASSEMBLY
• BODY MOUNTED PITCH YAW GYRO
• UNIFIED S-BAND EQUIPMENT
• PREMODULATION PROCESSOR POWER SUPPLY
• FM AND PM MIXING NETWORK
• DEEP SPACE UP VOICE DISCRIMINATOR
• PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
• AUDIO CENTER TRANSMITTER
• MICROPHONE
• PRE-MODULATED PROCESSOR, EMERGENCY KEY
• EMERGENCY KEY
• CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
• AUDIO CENTER, RECEIVER
• HEAD SET
• S-BAND POWER AMPLIFIER
PRE-MODULATION PROCESSOR UP DATE
• APOLLO GUIDANCE COMPUTER
• UP-DATA LINK


CONFIGURATION B
CAUTION & WARNING SUBSYSTEM
THREE AXIS ROTATIONAL CONTROL - NORMAL
RATE GYRO (PITCH YAW)
RATE GYRO (ROLL)
RATE GYRO DEMODULATOR (ROLL)
RATE GYRO DEMODULATOR (PITCH YAW)
THREE AXIS ROTATIONAL CONTROL - DIRECT
ELECTRONIC CONTROL ASSEMBLY - ROLL
ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
REACTION JET DRIVER ASSEMBLY - S/M
BODY MOUNTED PITCH YAW GYRO
UNIFIED S-BAND EQUIPMENT
PREMODULATION PROCESSOR POWER SUPPLY
FM AND PM MIXING NETWORK
DEEP SPACE UP VOICE DISCRIMINATOR
PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
AUDIO CENTER TRANSMITTER
MICROPHONE
PRE-MODULATED PROCESSOR, EMERGENCY KEY
EMERGENCY KEY
CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
AUDIO CENTER, RECEIVER
HEAD SET
PRE-MODULATION PROCESSOR UP DATA
APOLLO GUIDANCE COMPUTER
UP-DATA LINK

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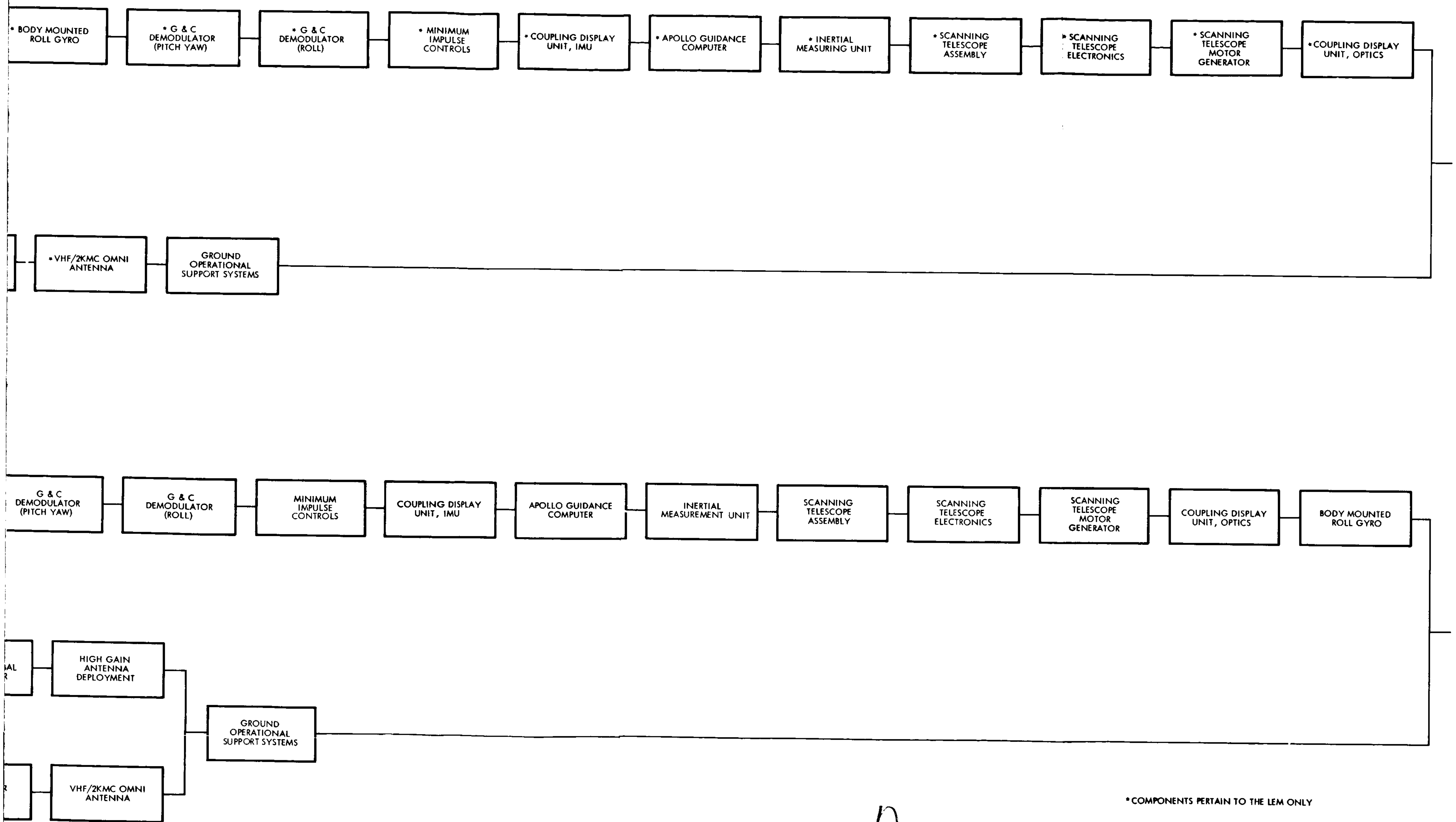
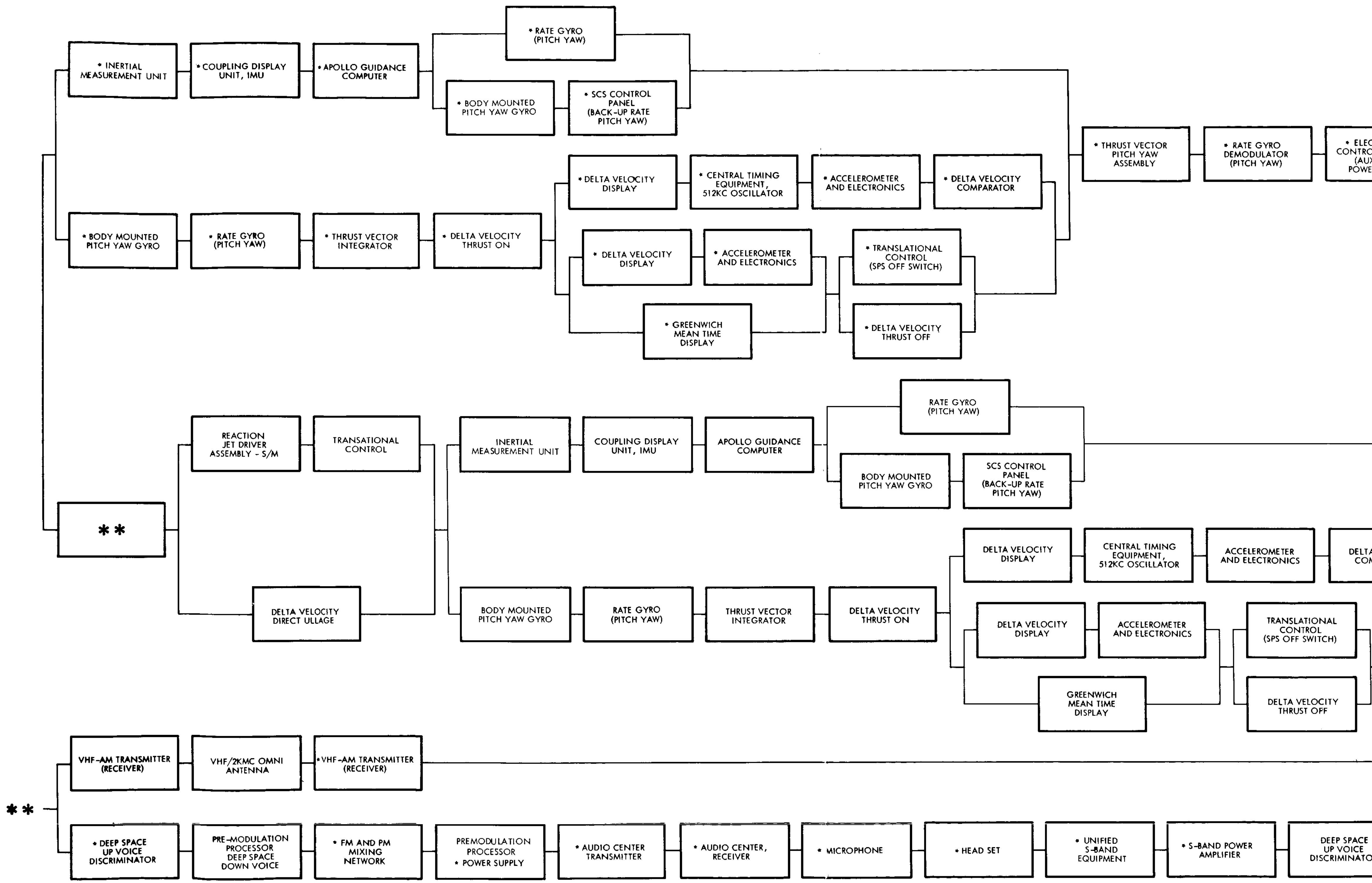


*COMPONENTS PERTAIN TO THE LEM ONLY

Figure 1-5. Thrust Vector Alignment (Sheet 2 of 2)

[redacted]



• INERTIAL MEASUREMENT UNIT
• COUPLING DISPLAY UNIT, IMU
• APOLLO GUIDANCE COMPUTER
• RATE GYRO (PITCH YAW)
• BODY MOUNTED PITCH YAW GYRO
• SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
• THRUST VECTOR PITCH YAW ASSEMBLY
• RATE GYRO DEMODULATOR (PITCH YAW)
• ELEC CONTROL (AUXI POWER
• BODY MOUNTED PITCH YAW GYRO
• RATE GYRO (PITCH YAW)
• THRUST VECTOR INTEGRATOR
• DELTA VELOCITY THRUST ON
• DELTA VELOCITY DISPLAY
• CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
• ACCELEROMETER AND ELECTRONICS
• DELTA VELOCITY COMPARATOR
• DELTA VELOCITY DISPLAY
• ACCELEROMETER AND ELECTRONICS
• TRANSLATIONAL CONTROL (SPS OFF SWITCH)
• GREENWICH MEAN TIME DISPLAY
• DELTA VELOCITY THRUST OFF
**
REACTION JET DRIVER ASSEMBLY - S/M
TRANSATIONAL CONTROL
DELTA VELOCITY DIRECT ULLAGE
INERTIAL MEASUREMENT UNIT
COUPLING DISPLAY UNIT, IMU
APOLLO GUIDANCE COMPUTER
RATE GYRO (PITCH YAW)
BODY MOUNTED PITCH YAW GYRO
SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
BODY MOUNTED PITCH YAW GYRO
RATE GYRO (PITCH YAW)
THRUST VECTOR INTEGRATOR
DELTA VELOCITY THRUST ON
DELTA VELOCITY DISPLAY
CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
ACCELEROMETER AND ELECTRONICS
DELTA COM
DELTA VELOCITY DISPLAY
ACCELEROMETER AND ELECTRONICS
TRANSLATIONAL CONTROL (SPS OFF SWITCH)
GREENWICH MEAN TIME DISPLAY
DELTA VELOCITY THRUST OFF
**
VHF-AM TRANSMITTER (RECEIVER)
VHF/2KMC OMNI ANTENNA
• VHF-AM TRANSMITTER (RECEIVER)
• DEEP SPACE UP VOICE DISCRIMINATOR
PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
• FM AND PM MIXING NETWORK
PREMODULATION PROCESSOR • POWER SUPPLY
• AUDIO CENTER TRANSMITTER
• AUDIO CENTER, RECEIVER
• MICROPHONE
• HEAD SET
• UNIFIED S-BAND EQUIPMENT
• S-BAND POWER AMPLIFIER
DEEP SPACE UP VOICE DISCRIMINATOR

[redacted]

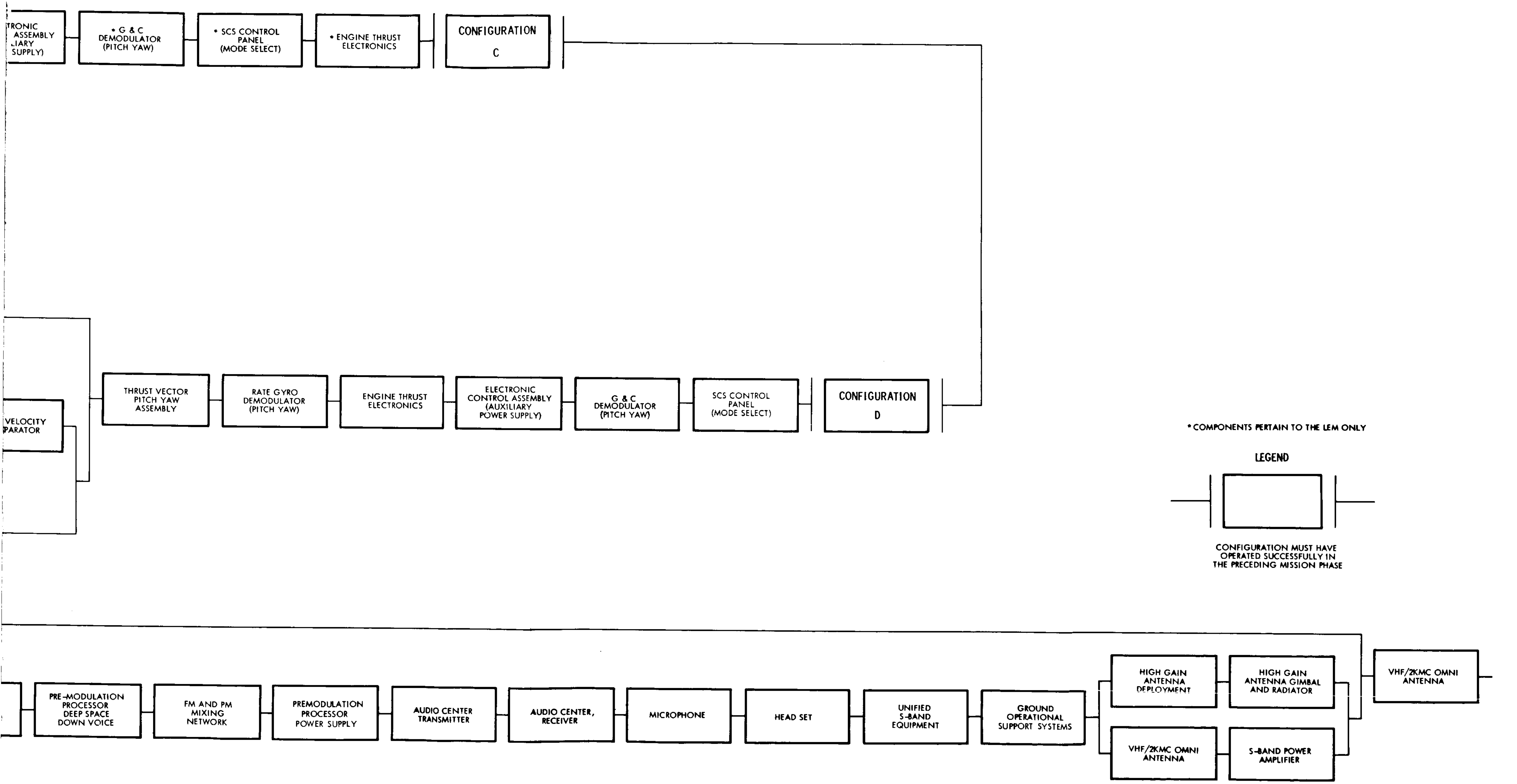


Figure 1-6. ΔV Firing (Sheet 1 of 2)

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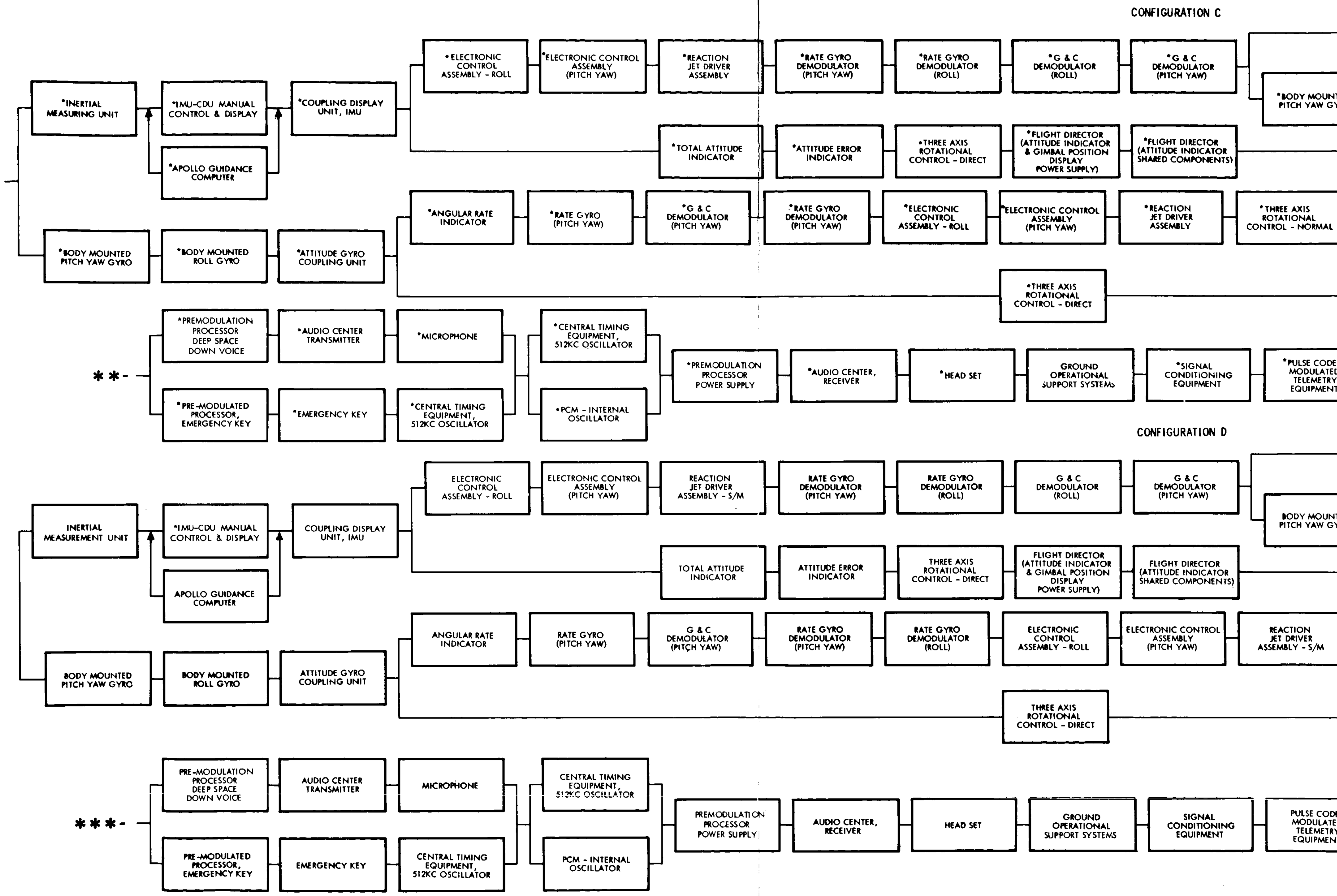
CONFIGURATION C
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*IMU-CDU MANUAL CONTROL & DISPLAY
*APOLLO GUIDANCE COMPUTER
*COUPLING DISPLAY UNIT, IMU
*ELECTRONIC CONTROL ASSEMBLY - ROLL
*ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
*REACTION JET DRIVER ASSEMBLY
*RATE GYRO DEMODULATOR (PITCH YAW)
*RATE GYRO DEMODULATOR (ROLL)
*G & C DEMODULATOR (ROLL)
*G & C DEMODULATOR (PITCH YAW)
*TOTAL ATTITUDE INDICATOR
*ATTITUDE ERROR INDICATOR
*THREE AXIS ROTATIONAL CONTROL - DIRECT
*FLIGHT DIRECTOR (ATTITUDE INDICATOR & GIMBAL POSITION DISPLAY POWER SUPPLY)
*FLIGHT DIRECTOR (ATTITUDE INDICATOR SHARED COMPONENTS)
*BODY MOUNTED PITCH YAW GYRO
*BODY MOUNTED ROLL GYRO
*ATTITUDE GYRO COUPLING UNIT
*ANGULAR RATE INDICATOR
*RATE GYRO (PITCH YAW)
*G & C DEMODULATOR (PITCH YAW)
*RATE GYRO DEMODULATOR (PITCH YAW)
*ELECTRONIC CONTROL ASSEMBLY - ROLL
*ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
*REACTION JET DRIVER ASSEMBLY
*THREE AXIS ROTATIONAL CONTROL - NORMAL
*THREE AXIS ROTATIONAL CONTROL - DIRECT
**-
*PREMODULATION PROCESSOR DEEP SPACE DOWN VOICE
*AUDIO CENTER TRANSMITTER
*MICROPHONE
*CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
*PRE-MODULATED PROCESSOR, EMERGENCY KEY
*EMERGENCY KEY
*CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
*PCM - INTERNAL OSCILLATOR
*PREMODULATION PROCESSOR POWER SUPPLY
*AUDIO CENTER, RECEIVER
*HEAD SET
GROUND OPERATIONAL SUPPORT SYSTEMS
*SIGNAL CONDITIONING EQUIPMENT
*PULSE CODE MODULATED TELEMETRY EQUIPMENT
CONFIGURATION D
INERTIAL MEASUREMENT UNIT
*IMU-CDU MANUAL CONTROL & DISPLAY
APOLLO GUIDANCE COMPUTER
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ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
REACTION JET DRIVER ASSEMBLY - S/M
RATE GYRO DEMODULATOR (PITCH YAW)
RATE GYRO DEMODULATOR (ROLL)
G & C DEMODULATOR (ROLL)
G & C DEMODULATOR (PITCH YAW)
BODY MOUNTED PITCH YAW GYRO
TOTAL ATTITUDE INDICATOR
ATTITUDE ERROR INDICATOR
THREE AXIS ROTATIONAL CONTROL - DIRECT
FLIGHT DIRECTOR (ATTITUDE INDICATOR & GIMBAL POSITION DISPLAY POWER SUPPLY)
FLIGHT DIRECTOR (ATTITUDE INDICATOR SHARED COMPONENTS)
BODY MOUNTED PITCH YAW GYRO
BODY MOUNTED ROLL GYRO
ATTITUDE GYRO COUPLING UNIT
ANGULAR RATE INDICATOR
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RATE GYRO DEMODULATOR (ROLL)
ELECTRONIC CONTROL ASSEMBLY - ROLL
ELECTRONIC CONTROL ASSEMBLY (PITCH YAW)
REACTION JET DRIVER ASSEMBLY - S/M
THREE AXIS ROTATIONAL CONTROL - DIRECT
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PRE-MODULATION PROCESSOR DEEP SPACE DOWN VOICE
AUDIO CENTER TRANSMITTER
MICROPHONE
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PRE-MODULATED PROCESSOR, EMERGENCY KEY
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CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
PCM - INTERNAL OSCILLATOR
PREMODULATION PROCESSOR POWER SUPPLY
AUDIO CENTER, RECEIVER
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GROUND OPERATIONAL SUPPORT SYSTEMS
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PULSE CODE MODULATED TELEMETRY EQUIPMENT

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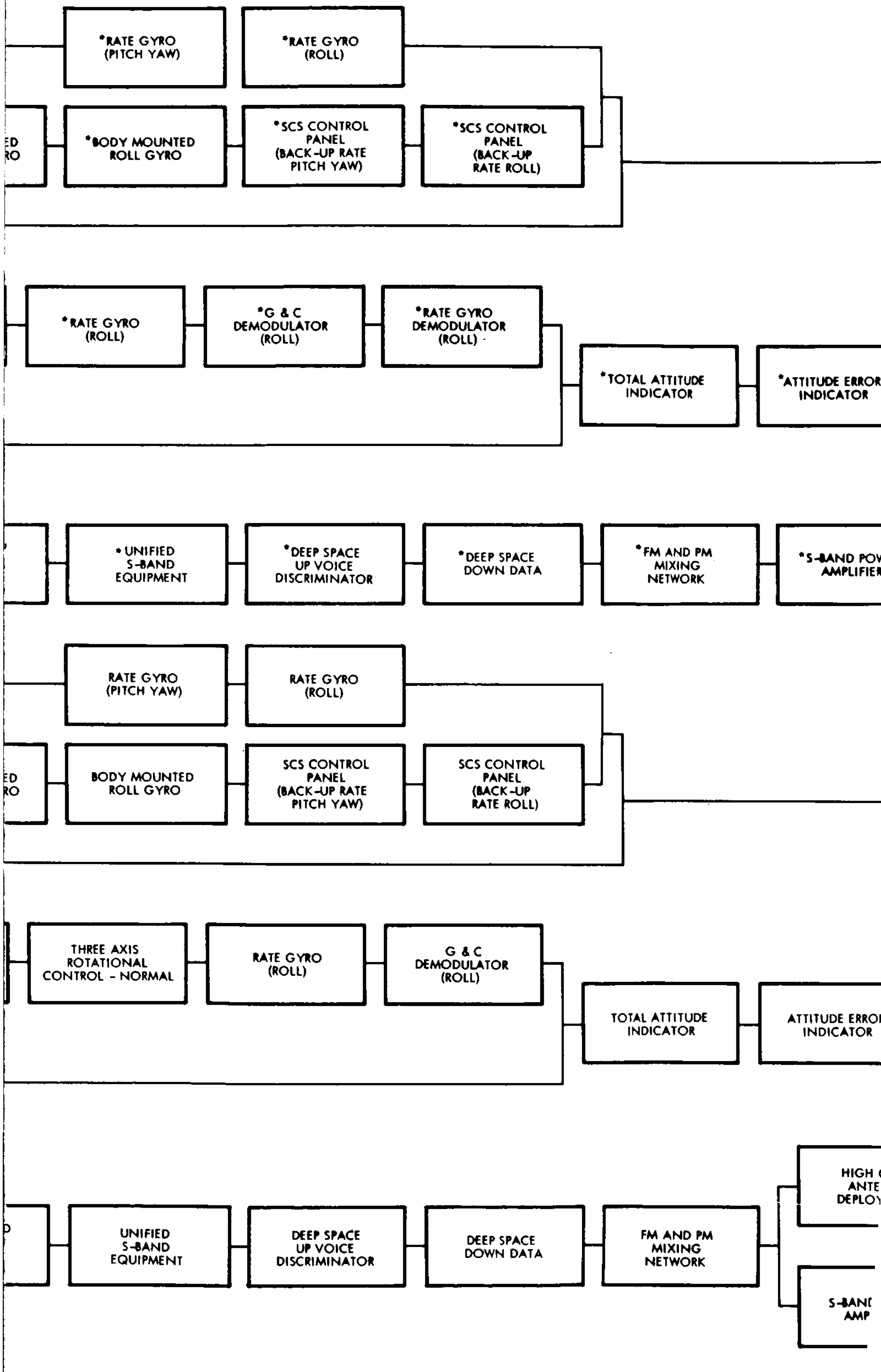

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*RATE GYRO (ROLL)
*BODY MOUNTED ROLL GYRO
*SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
*SCS CONTROL PANEL (BACK-UP RATE ROLL)
*RATE GYRO (ROLL)
*G & C DEMODULATOR (ROLL)
*RATE GYRO DEMODULATOR (ROLL)
*TOTAL ATTITUDE INDICATOR
*ATTITUDE ERROR INDICATOR
*UNIFIED S-BAND EQUIPMENT
*DEEP SPACE UP VOICE DISCRIMINATOR
*DEEP SPACE DOWN DATA
*FM AND PM MIXING NETWORK
RATE GYRO (PITCH YAW)
RATE GYRO (ROLL)
BODY MOUNTED ROLL GYRO
SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
SCS CONTROL PANEL (BACK-UP RATE ROLL)
THREE AXIS ROTATIONAL CONTROL - NORMAL
RATE GYRO (ROLL)
G & C DEMODULATOR (ROLL)
TOTAL ATTITUDE INDICATOR
UNIFIED S-BAND EQUIPMENT
DEEP SPACE UP VOICE DISCRIMINATOR
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FM AND PM MIXING NETWORK

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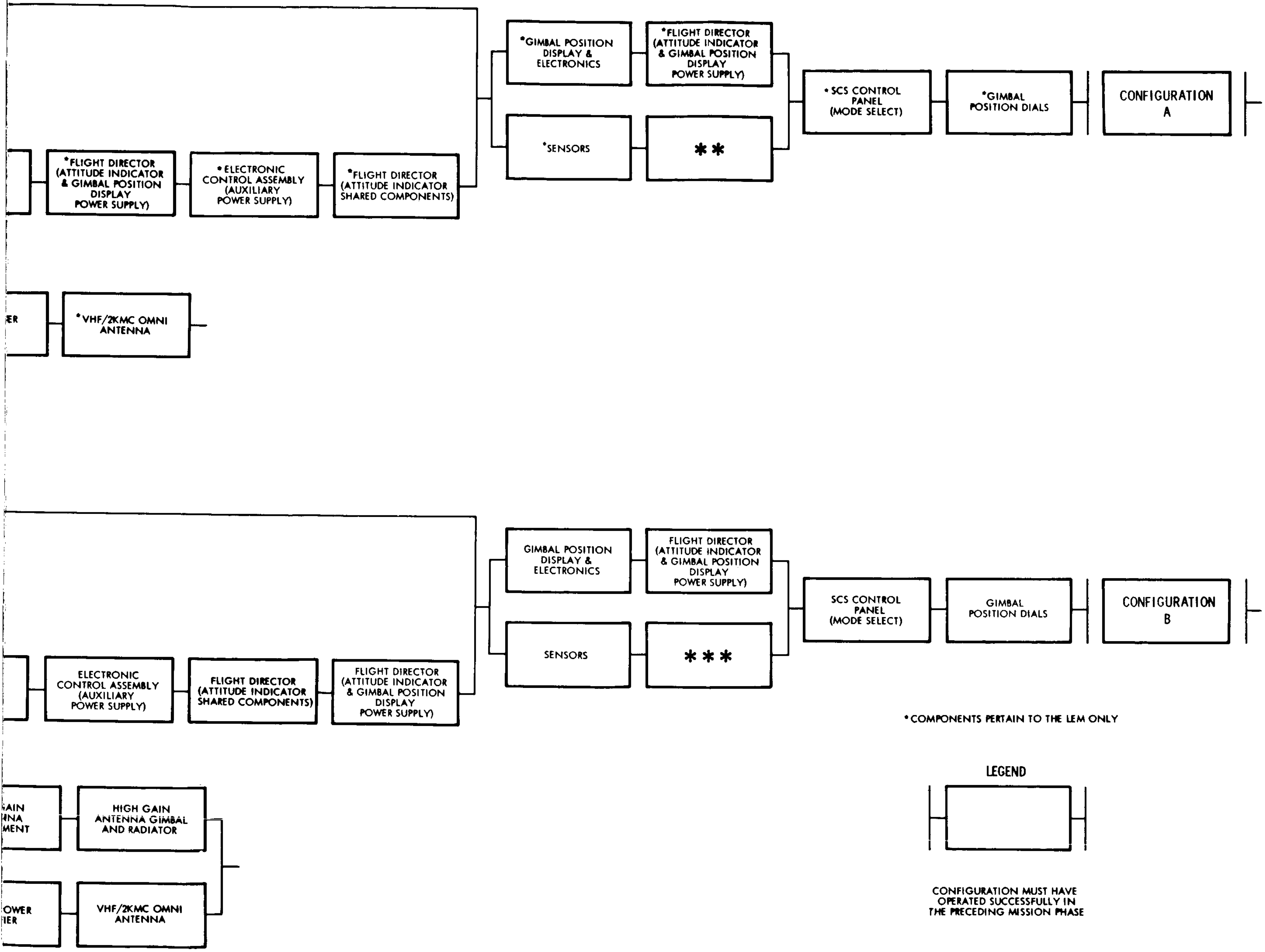

Figure 1-6. ΔV Firing (Sheet 2 of 2)

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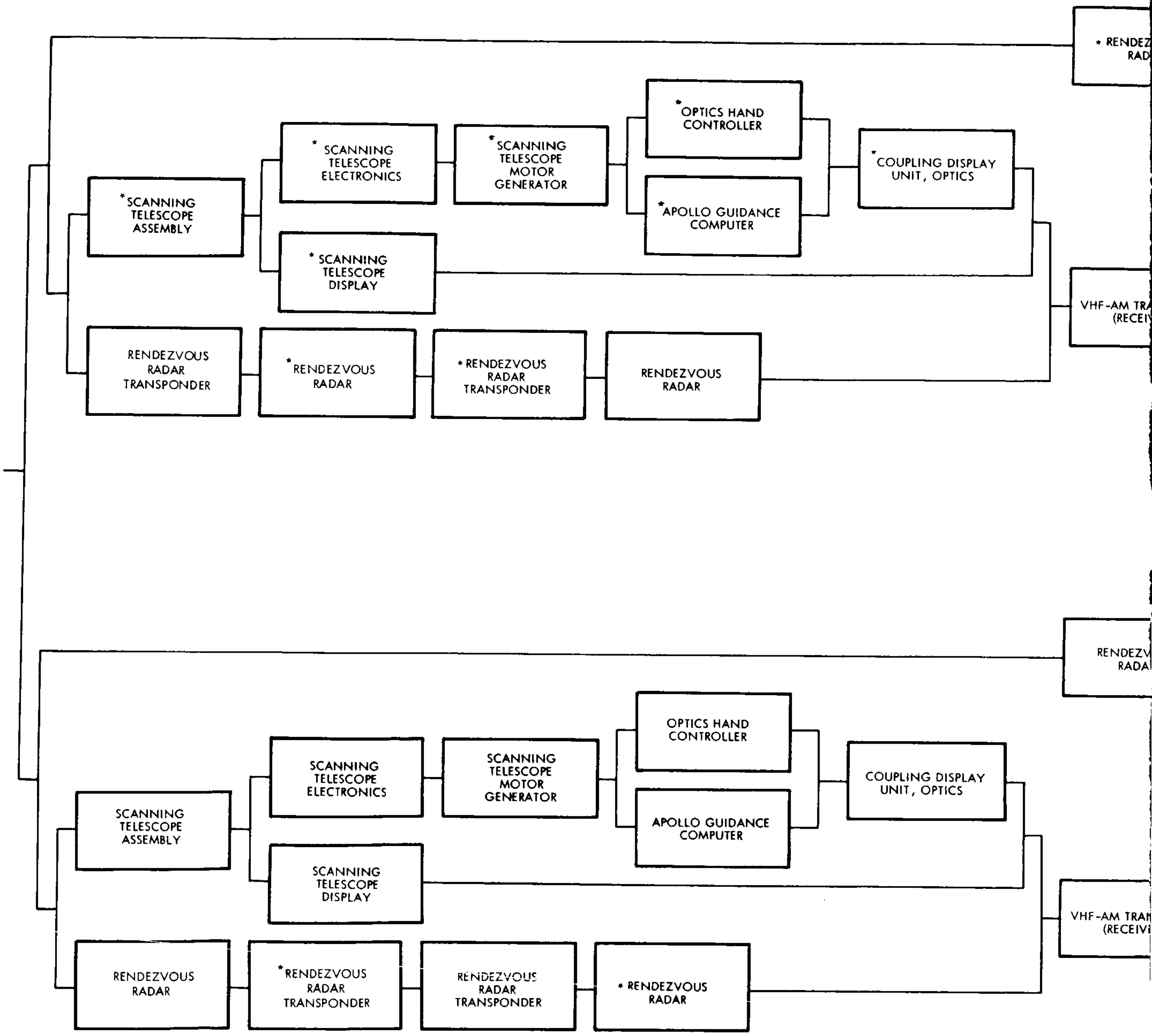
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* SCANNING TELESCOPE ELECTRONICS
*SCANNING TELESCOPE MOTOR GENERATOR
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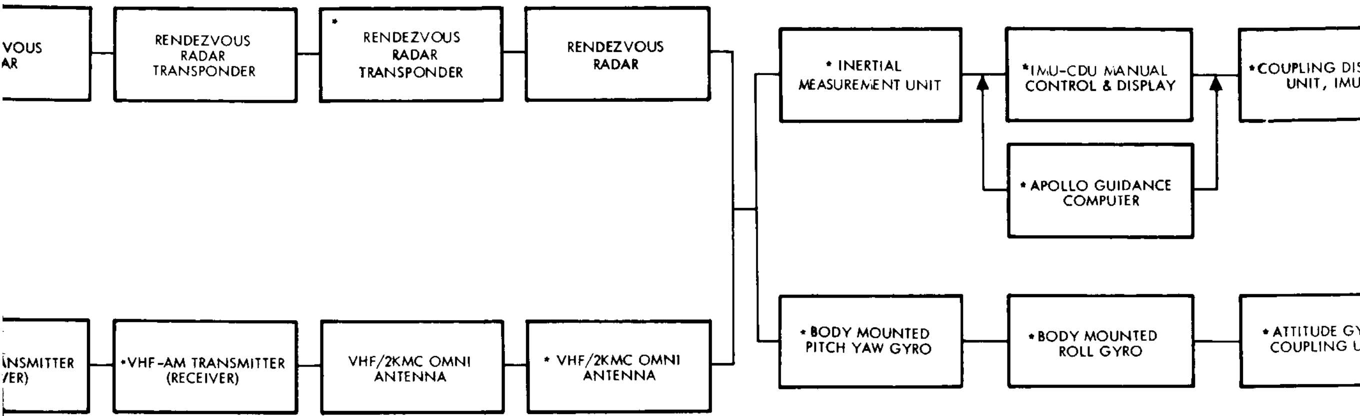
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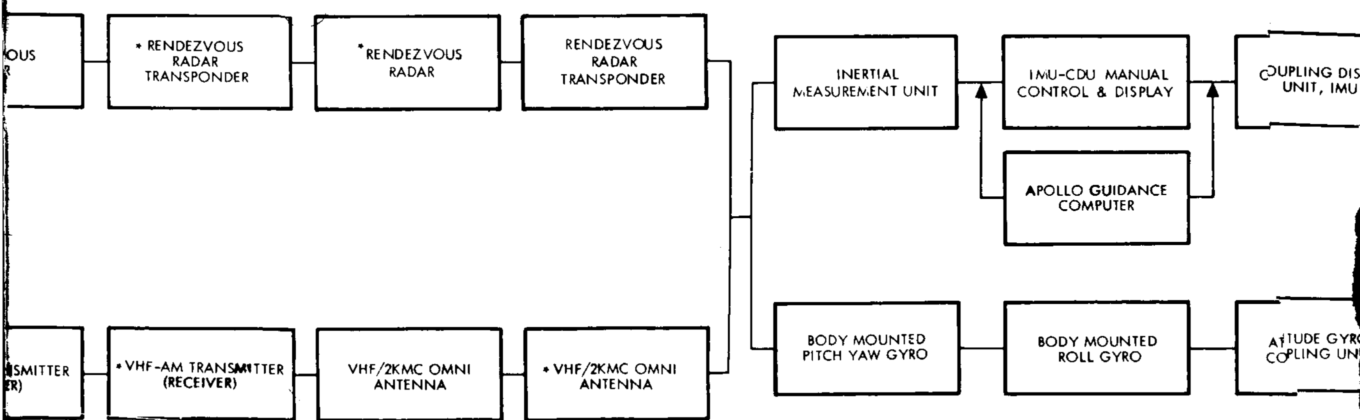
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* RENDEZVOUS RADAR
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INERTIAL MEASUREMENT UNIT
IMU-CDU MANUAL CONTROL & DISPLAY
COUPLING DIS
UNIT, IMU
APOLLO GUIDANCE COMPUTER
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R)
* VHF-AM TRANSMITTER (RECEIVER)
VHF/2KMC OMNI ANTENNA
* VHF/2KMC OMNI ANTENNA
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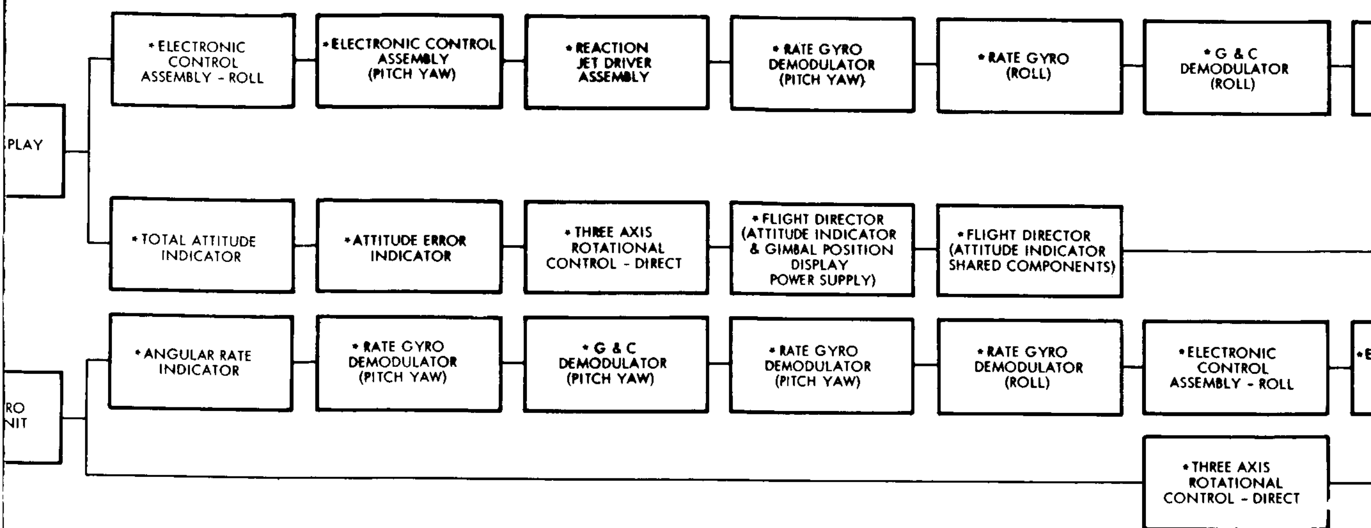

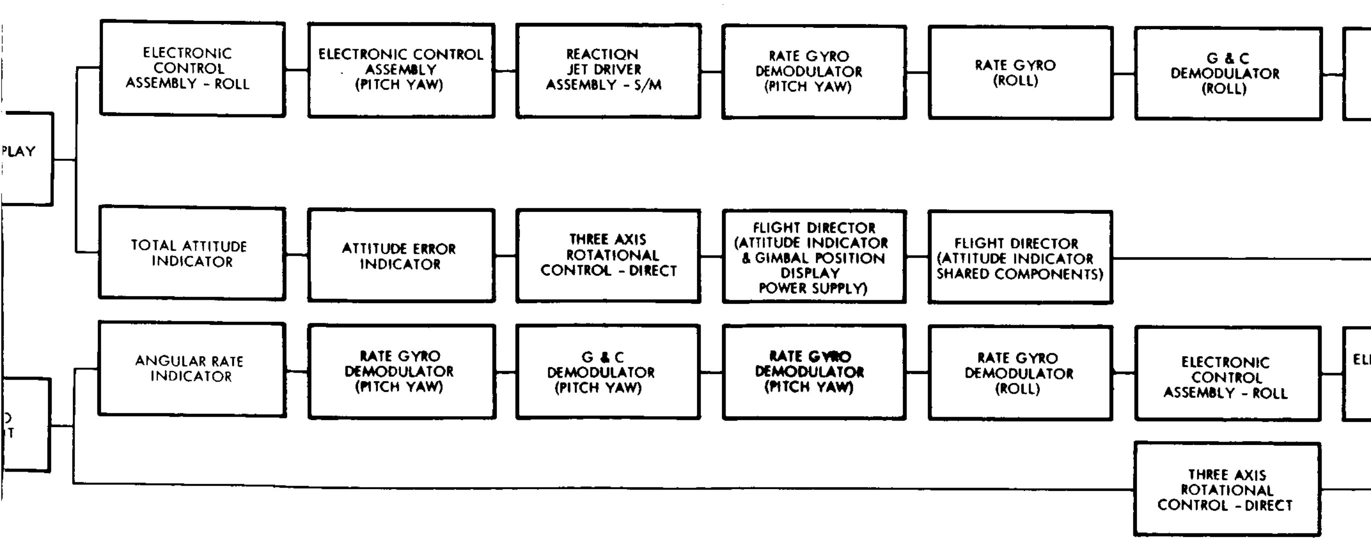

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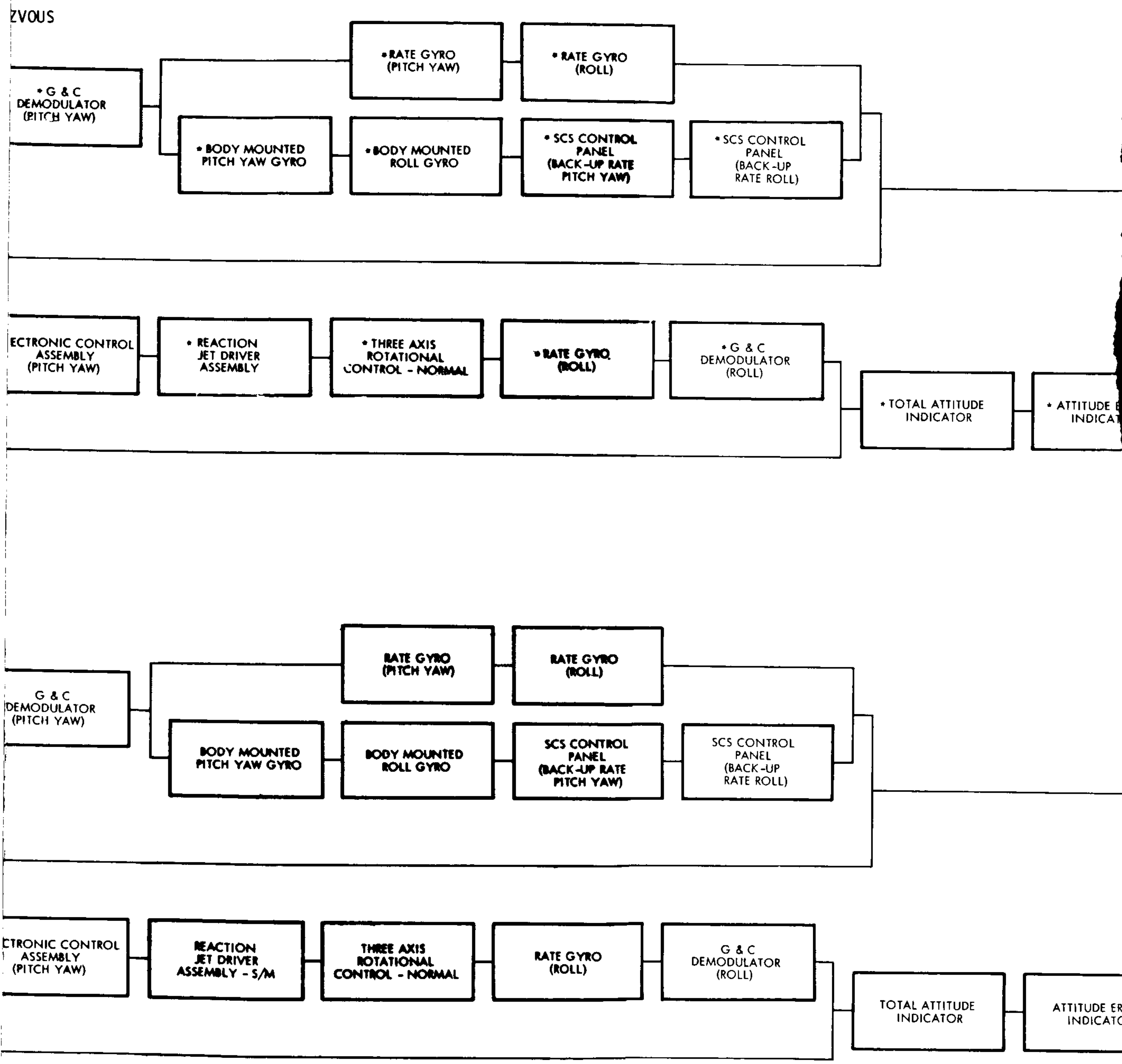

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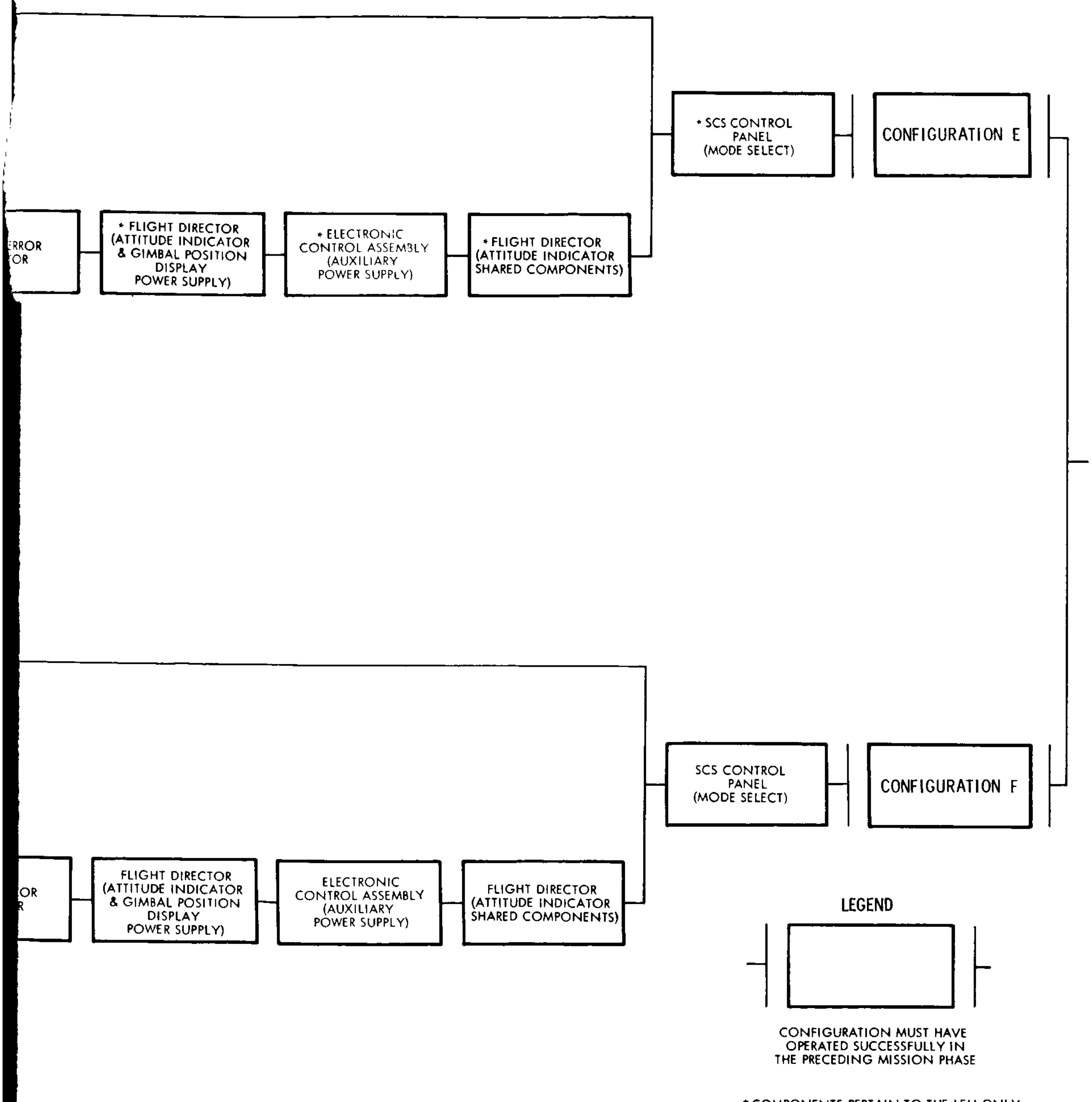

Figure 1-7. Terminal Rendezvous (Sheet 1 of 2)

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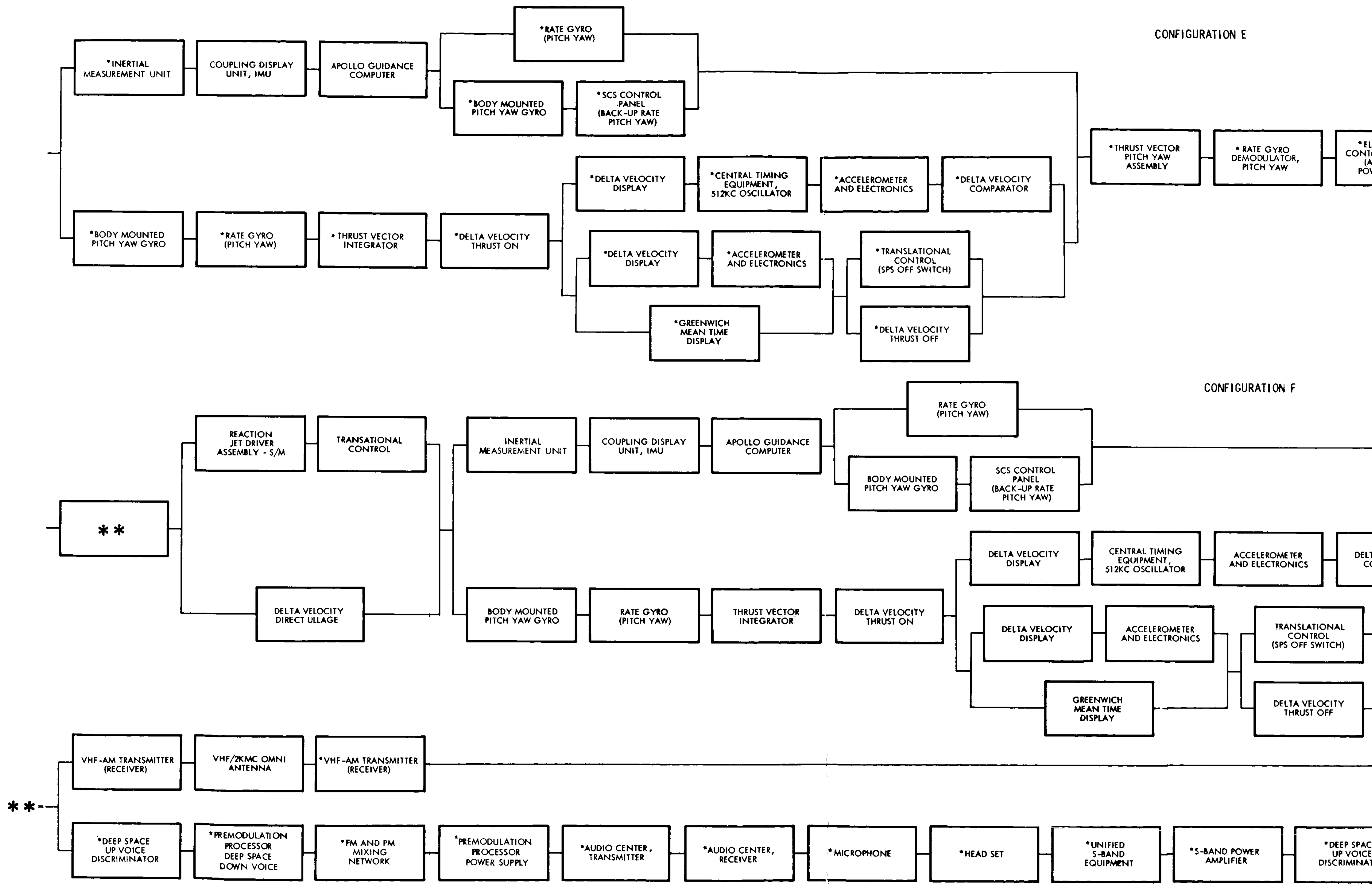
CONFIGURATION E
*INERTIAL MEASUREMENT UNIT
COUPLING DISPLAY UNIT, IMU
APOLLO GUIDANCE COMPUTER
*RATE GYRO (PITCH YAW)
*BODY MOUNTED PITCH YAW GYRO
*SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
*THRUST VECTOR PITCH YAW ASSEMBLY
*RATE GYRO DEMODULATOR, PITCH YAW
*BODY MOUNTED PITCH YAW GYRO
*RATE GYRO (PITCH YAW)
*THRUST VECTOR INTEGRATOR
*DELTA VELOCITY THRUST ON
*DELTA VELOCITY DISPLAY
*CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
*ACCELEROMETER AND ELECTRONICS
*DELTA VELOCITY COMPARATOR
*DELTA VELOCITY DISPLAY
*ACCELEROMETER AND ELECTRONICS
*GREENWICH MEAN TIME DISPLAY
*TRANSLATIONAL CONTROL (SPS OFF SWITCH)
*DELTA VELOCITY THRUST OFF
CONFIGURATION F
* *
REACTION JET DRIVER ASSEMBLY - S/M
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INERTIAL MEASUREMENT UNIT
COUPLING DISPLAY UNIT, IMU
APOLLO GUIDANCE COMPUTER
RATE GYRO (PITCH YAW)
BODY MOUNTED PITCH YAW GYRO
SCS CONTROL PANEL (BACK-UP RATE PITCH YAW)
BODY MOUNTED PITCH YAW GYRO
RATE GYRO (PITCH YAW)
THRUST VECTOR INTEGRATOR
DELTA VELOCITY THRUST ON
DELTA VELOCITY DISPLAY
CENTRAL TIMING EQUIPMENT, 512KC OSCILLATOR
ACCELEROMETER AND ELECTRONICS
DELTA
DELTA VELOCITY DISPLAY
ACCELEROMETER AND ELECTRONICS
GREENWICH MEAN TIME DISPLAY
TRANSLATIONAL CONTROL (SPS OFF SWITCH)
DELTA VELOCITY THRUST OFF
* *
VHF-AM TRANSMITTER (RECEIVER)
VHF/2KMC OMNI ANTENNA
*VHF-AM TRANSMITTER (RECEIVER)
*DEEP SPACE UP VOICE DISCRIMINATOR
*PREMODULATION PROCESSOR DEEP SPACE DOWN VOICE
*FM AND PM MIXING NETWORK
*PREMODULATION PROCESSOR POWER SUPPLY
*AUDIO CENTER, TRANSMITTER
*AUDIO CENTER, RECEIVER
*MICROPHONE
*HEAD SET
*UNIFIED S-BAND EQUIPMENT
*S-BAND POWER AMPLIFIER
*DEEP SPACE UP VOICE

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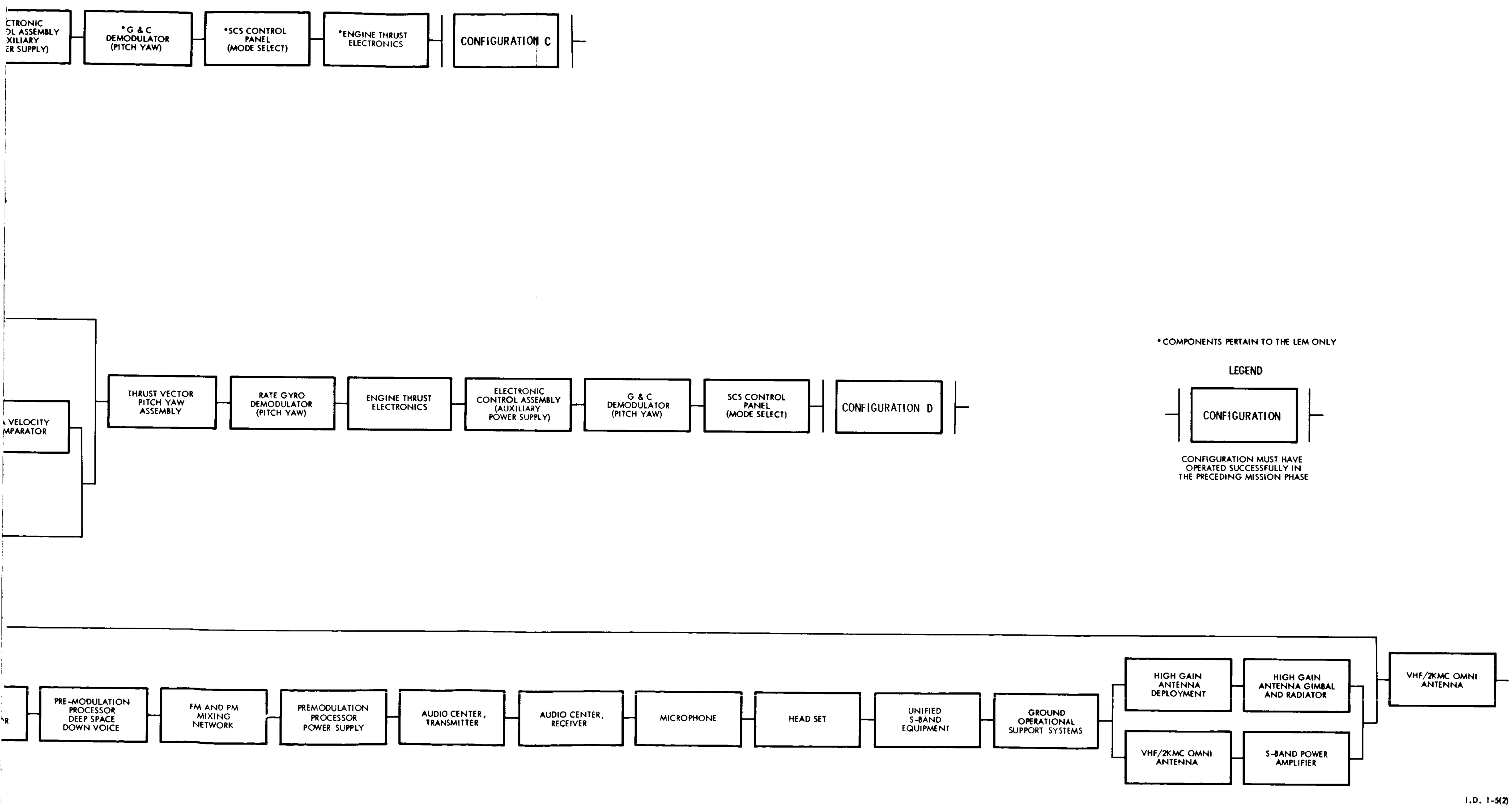

Figure 1-7. Terminal Rendezvous (Sheet 2 of 2)

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INTEGRATED SYSTEM AND BOILERPLATE TEST

SUMMARY

Integrated System Test

Detailed operating procedures for obtaining reliability data from WSMR have been developed. Discrepancy Reports are to be used to document all nonconformances. Non-Conformance Reports (NCR) will be written to document all failures and unsatisfactory conditions requiring reliability analysis and action by S&ID. During the period covered by this report, 39 NCR were written at WSMR; all were followed by immediate corrective action and 18 await final corrective action.

Rapid communication has been established between WSMR and S&ID to provide prompt transmission of failure data and status reports, and to ensure that the necessary corrective action is taken. Telephone calls, NCR and advance copies of NCAR (Non-Conformance Analysis Reports) will be the principal forms of communication. Distribution lists for the various failure reporting documents have been established. In general, it is anticipated that procedures established at WSMR will be used at AMR and Houston.

STATUS

Boilerplate 6 Test

All tests required to establish interim qualification have been completed except as shown in Table 1-4. The unsatisfactory flight of Boilerplate 3 indicated that the smoothing of the sharp edges of the CM structure, in addition to some minor improvements in the parachute shrouds, would increase the reliability of the earth landing system. The Boilerplate 6 flight was delayed to incorporate these changes.

[redacted]

[redacted]

Table 1-4. Status of Boilerplate 6 Equipment Items (Incomplete Qualification)

Part No.	Title	Test Status
R6010-3 ME 453-0005-0011	Drogue Mortar Assembly Pressure Cartridge, Type I	Six more tests are scheduled on each type mortar for drogue and pilot
R6040-3 ME 453-0005-0012	Pilot Mortar Assembly Pressure Cartridge, Type II	
2. 3. 2. 1. 3	Rate Gyro	A letter has been published and sent to NASA requesting a deviation on qualification test requirements for this item. (Ref. to ARET-63-8-76.)

Boilerplates 12 and 13

Test and checkout of Boilerplates 12 and 13 have been delayed to allow design changes in the flight test vehicle. Consequently, integrated system test activity has been at a minimum during the period covered by this report.

PLANNED ACTIVITIES

An improvement in the NCR and its handling procedure is anticipated during the next quarter to facilitate handling of reliability hardware problems. This improvement will be evaluated during test and checkout of Boilerplates 12 and 13.

[redacted]

APOLLO DESIGN REVIEW

SUMMARY

Apollo design reviews are conducted in accordance with S&ID Policies and Procedures C430. The reliability manager is chairman of the Design Review Board. His responsibilities include scheduling, distribution of review material, coordination and evaluation before the meeting, presiding at the meeting and preparation of meeting reports.

STATUS

Table 1-5 summarizes the Apollo design review activity to date and includes the reviews conducted during the last quarter.

The number of action items listed as open will not be considered closed until resolution of the items within the responsible S&ID department. The action must be satisfactory to all board members. Final action may not be fully resolved until the next Apollo design review scheduled for the particular system. All action items assigned to a particular end item must be resolved prior to final testing. A summary of the Waste Management System Design Review is presented under the Crew Provisions section of this report.

Preliminary Apollo design reviews for the reaction control system (RCS) and Boilerplate 12 were scheduled during the last quarter but were rescheduled for a later date to accommodate technological changes (reference MCR A269 and A345).

[redacted]

[redacted]

Table 1-5. Apollo Design Review Status

DR No.	Title	Review Date	Type of Review	Board-Recommended* Action Items	No. of Board-Recommended Action Items	No. of Action Items Remaining Open
1	Environmental Control System	12-18-62	Preliminary	Approved	7	4
2**	Earth Landing Subsystem	2-11-63	Preliminary	Approved	4	0
3	Launch Escape Subsystem	2-21-63	Preliminary	Approved	7	5
4	Electrical Distribution Subsystem	3-11-63	Preliminary	Approved	8	3
5	Service Propulsion System	4-11-63	Preliminary	Approved	3	3
6	Cryogenic Storage System	4-9-63	Preliminary	Approved	6	1
7***	In-Flight Test System	6-19-63	Preliminary	Approved	9	9
8	Boilerplate No. 6 (End Item)	4-30-63	Preflight	Approved	15	7
9	Waste Management System	6-5-63	Preliminary	Approved	12	3
10	Fuel Cell	6-13-63	Preliminary	Approved	8	5
11***	Stabilization & Control System	7-2-63	Preliminary	Approved	7	6

*Approval contingent upon successful resolution of action items.
**To be removed from next Quarterly Report.
***Reviews held from 16 June 1963 to 15 September 1963.

[redacted]

II. MECHANICAL SUBSYSTEM ANALYSIS

COMMAND MODULE REACTION CONTROL

SUMMARY

Progress toward the CM RCS engine reliability goal is proceeding satisfactorily. The most important remaining development problems are inability to achieve the zero internal leak rate specified for the propellant valves and excessive charring of the ablative material in certain types of pulse-mode operation. A final method for reliability assessment has not yet been determined.

The following activities were undertaken or accomplished during the report period.

RELIABILITY/CREW-SAFETY DESIGN REVIEW

A joint S&ID-Rocketdyne design review was conducted on propellant valves. Although the valves have exhibited high cyclic reliability in functional testing, several potential problem areas were defined. These include inability of the subcontractor to meet the zero internal leakage rate specified, a potential filter maintenance problem, and possible excessive tolerance buildup in several areas. Remedial action has been initiated. Qualification testing of the latest engine configuration, including prototype values, is expected to begin no later than 11 November 1963.

PROBLEM AREAS

Weld development difficulties (mainly excessive porosity) in fabrication of the propellant tanks have occurred. Six of seven tank shells were rejected because of discrepant welds. Difficulty has been experienced in establishing methods of determining permeation rates of the propellant tank expulsion bladder. Manufacturing problems have developed in the fabrication of the reaction control engine; construction of thrust chamber parts has become more complex and difficult than anticipated.

[redacted]

[redacted]

[redacted]

TEST PROGRAM

Physical problems have been encountered in instrumentation response time for pulse-mode operation. Previous attempts to develop a satisfactory flow rate measuring system have been unsuccessful; therefore, in order to facilitate solution of the problem, particular effort is being devoted to instrumentation.

Information supplied for inclusion in Volume IV (Ground Qualification Tests) of the revised Apollo General Test Plan, SID 62-109, included an outline of the system test program, a system logic diagram, a presentation of system criticality versus hardware requirements, and updated qualification test schedules with test specimen utilization.

The component vendor selection including placement of purchase orders, is approximately 97 percent complete. Approximately 80 percent of the 14 selected vendors have begun preliminary development testing.

A major improvement in expulsion bladder fabrication has resulted in increased ply resistance to separation upon exposure to propellants.

SUBCONTRACTOR MANAGEMENT

Subcontractor Activities

In response to an S&ID request, the engine subcontractor has provided a reliability assessment based on hot firings of developmental thrust chamber assemblies. Using an exponential distribution, the test data yielded a reliability estimate of 45 percent for a 130-second firing duration, considering only those failures classified as "significant." Propellant valve cycle reliability based on separate cyclic data is estimated at 99.8 percent at a 90-percent confidence level for each open and closed cycle.

A monthly reliability data review has been established with the subcontractor. Each month the results of all hot firings will be reviewed by the S&ID reliability representative, test classifications will be verified, and the effectiveness of the failure reporting system will be checked.

Rocketdyne response to S&ID comments on the Reliability Program Plan has been received and is in the process of review.

Subcontractor Coordination

An interpretation of the requirements of the identification and traceability document, MA 0201-0209, was presented to Rocketdyne and

[redacted]

[redacted]

procedures have been instituted by the subcontractor to ensure adequate program scope to meet those requirements. A proposal will be submitted by Rocketdyne to S&ID by 30 October 1963 specifically defining this effort, including clarification of the response time and a list of exempted items. Identification and traceability for all deliverable qualification hardware is planned as a Rocketdyne quality control function.

PLANNED ACTIVITIES

Efforts to establish methods for determining permeation rates for the propellant tank expulsion bladder will continue. In addition, a satisfactory weld procedure will be established for fabrication of the propellant tank shells.

Improved manufacturing procedures for the fabrication of the CMRCS engine are to be developed. Development tests on the prototype engine will include steady-state, pulse, mission duty, and off-nominal firing conditions.

All vendors will begin specific component development tests on prototype configuration hardware for all items before the end of the next quarter.

Component design verification and qualification tests are scheduled to begin for approximately 30 percent of the components. Specific initiation dates for the engine qualification tests have not been stated, but these are anticipated by the latter part of the next quarter.

[redacted]

[redacted]

COMMAND MODULE HEAT SHIELD

SUMMARY

A preliminary mathematical model based on failure mechanism methodology is being investigated. The model represents the design configuration with reasonable accuracy, but it is somewhat less detailed than the design equation presently being developed and will be used to supplement the equational results. The failure rate apportionment will be based on failures per square foot of area/specialized item/linear foot of heat shield. This approach should provide a relatively simple apportionment technique whereby the net effect of design changes on the reliability of the heat shield should be readily determinable.

ANALYSIS

The effort continues to establish the best reliability estimate using development test data. Data reduction is being approached with a regard for possible compounding of the input variables. The analysis is to be carried out in two phases. Initially the analysis will utilize a sequential regression technique based on first- and second-degree input variables in a linear regression model. Canonical reduction of the resulting equations will lead to a refinement based on models more related to the physical situation. This will be based on the application of linear perturbation theory to a model derived from fundamental heat flow considerations.

The minimum and maximum ablator margins of safety during atmospheric entry were determined from envelope curves for maximum compressive stresses during entry and ultimate compressive stresses as a function of temperature. Strain envelope curves corresponding to the stress curves were obtained, on a uniaxial basis for a conservative approach, and the margins for both the parallel and perpendicular directions obtained are summarized.

Temperature (^{o}F)	Margin of Safety	
	Parallel to Honeycomb Ribbon	Perpendicular to Honeycomb Ribbon
+300	+1.17	No data taken
+350	No data taken	1.22
+600	+4.00	3.83

[redacted]

[redacted]

[redacted]

TEST PROGRAM

The development test program status is summarized in Tables 2-1, 2-2 and 2-3. No qualification tests were initiated during this period.

Table 2-1. Structural Development Tests

Type of Test	Number of Specimens Planned	Number of Specimens Tested	Percent Completed
Cold soak evaluation	37	62	167
Flat panel reentry	16	12	72
Temperature gradient	21	22	102
Beams	8	6	75
Stress concentration	32	13	41
Curved panel reentry	16	4	25
Panel sequential and cyclic	68	50	74
Special design probe	9	7	78
Dynamic test	4	2	50
Repair evaluation	9	0	0
Total	220	178	81

[redacted]

Table 2-2. Thermal, Optical, and Ablation Tests

Type of Test	Number of Tests Planned	Number of Tests Completed	Percent Completed
Thermal conductivity	367	261	71
Specific heat	137	79	58
Heat of degradation	35	5	14
Optical properties	279	85	31
Solar simulation	100	100	100
Model 500 arc (Q* and ascent)	700	436	62
OVERS stagnation heating	894	605	68
OVERS two-dimensional	371	90	24
10-mw arc turbulent pipes	337	127	38
Sequential ablation	81	0	0
Total	3301	1788	54

Table 2-3. Mechanical Property Tests

Test	Number of Tests Planned	Number of Tests Completed	Percent Completed
Tensile	2660	2060	77
Compressive	1176	618	53
Shear	332	199	80
Thermal and moisture expansion	1024	412	40
Bond	1570	1565	99
Total	6762	4845	72

[redacted]

[redacted]

PLANNED ACTIVITIES

The following tests will be conducted at AVCO during the next quarter.

1. Cold soak tests
2. Temperature gradient tests
3. Bolt plug tests
4. Door panel tests
5. Shear compression pad radiant lamp tests
6. Flat panel seal gasket radiant heat tests
7. Flat panel splice joints radiant heat tests
8. Cold and hot soak intercompartment seal tests

[redacted]

[redacted]

CREW PROVISIONS

SUMMARY

An Apollo design review was completed for the waste management system. Human engineering and interface evaluation studies are estimated to be 20 percent complete. No suppliers have been selected to date for the crew personal equipment and survival gear contracts. Development tests of the waste management system are approximately 40 percent complete.

APOLLO DESIGN REVIEW

The most significant items discussed at the Waste Management Design Review are the following:

1. A problem concerning the urine separator control unit backup valve, while in the urine overboard position, is being investigated. This valve and the interconnecting lines may freeze up since they will be exposed to both urine and hard vacuum when the valve is in the overboard position.

2. The incorporation of a vent in the separator wall is being investigated, since the volume and pressure of air trapped in the chamber is small and can conceivably drop to zero before expulsion is complete. This could cause the remaining urine to boil off, leaving solids in the separator and line.

3. The feasibility of redesigning the control valve configuration for sequential modes of operation is being investigated since operation of the blower motor between the vacuum cleaner and the urine/feces positions is not required.

4. A study is being performed to determine remedial action in preventing the overboard urine disposal line from plugging up. Action is necessary because the line will be full of urine after each overboard dumping and will start to boil or sublimate from the outlet back to the overboard valve.

[redacted]

TEST PROGRAM

The following tests were conducted during this reporting period.

1. Oxygen umbilical hose coupling leakage test. This test was conducted to evaluate the mating surfaces between the spring loaded coupling (prototype I) of the umbilical oxygen hose and the environmental control system controller.

2. Evaluation of C M lower equipment bay restraint systems. Three types of restraint systems were evaluated. The "net" concept was found most desirable because it is adaptable to the constant wear garment used by crew members.

3. Evaluation of crew access to cabin side consoles as kick ring protrusion is varied. Test subjects in pressurized suits were used for this test. The data is being analyzed for comparison of the percentage of structural strength lost and console access gained.

4. Sextant Evaluation Study. Crew performance during navigation sightings is being studied using a simulated space sextant.

5. Shock Strut Evaluation Study. A crew performance test relative to shock strut adjustment release mechanism was conducted.

PLANNED ACTIVITIES

1. Drop tests utilizing instrumented anthropomorphic dummies

2. Evaluation tests of pressure suit

3. Evaluation tests of crew couch

4. Evaluation tests of harness assembly

5. Evaluation tests of mechanical seal of fecal bag

6. Functional evaluation of the fecal bag & canister

7. Centrifuge test program - the following areas will be investigated:

   Crew couch, suit and restraint harness interface
   Suitability of various acceleration profiles
   Control display design
   Human performance of manual function.

[redacted]

[redacted] [redacted]

CRYOGENIC STORAGE

SUMMARY

A reliability analysis of the cryogenic storage subsystem instrumentation was completed and the subcontractor reliability program was monitored. One problem area has developed concerning the titanium vessels. This problem is under study and should be solved in the near future. The reliability predictions currently meet the system reliability goals.

ANALYSIS

A reliability analysis of the cryogenic storage subsystem instrumentation was performed. The analysis showed the instrumentation to be adequate from the standpoint of numerical reliability. However, the failure effects analysis indicated the desirability of talkback indicators to indicate when the tank heaters are operative.

TEST PROGRAM

Titanium pressure vessel S/N 0011 ruptured during proof pressure test. The vessel had been subjected to proof pressure for 15 minutes before rupture occurred. Subsequent creep tests undertaken on upper and lower hemisphere test specimens resulted in low ultimate creep strength. Pressure vessel S/N 0007 failed below the proof pressure requirement. S/N 0009, which satisfactorily withstood the proof pressure and leak tests, is in manufacturing for insulation layup and will replace S/N 0007. Test results from these titanium pressure vessels indicate that the material exhibits significant creep characteristics at 85 percent of yield strength. A new design criterion, based on the latest creep data, has been approved.

Two oxygen outer shell hemispheres collapsed at a differential pressure of 7 psi.

A problem area exists in the welding of the skirt to the lower outer shell. The outer shell shrinks during the welding process, leaving the upper outer shell larger than the lower outer shell.

[redacted]

A liquid hydrogen valve module failed under test. It has since been modified and accepted.

Other recent test results for the cryogenic storage system are as follows:

1. The heater assembly of Engineering Model 1 was tested with satisfactory results and is being prepared for shipment.

2. Fan motor bearings have completed a 340-hour endurance test in liquid hydrogen.

3. Two rupture discs have been successfully tested.

SUBCONTRACTOR ACTIVITIES

Beech concentrated reliability effort on improving inherent design reliability and its retention during fabrication. Critical design and fabrication areas were determined and analyzed.

Beech revised the cryogenic storage subsystem failure mode and reliability analysis by incorporating environmental modifiers and refining the part level analysis. These improvements permit more accurate and realistic approximations of system reliability and provide for the detection of critical areas of design or fabrication.

A list of Beech items to be exempted from identification and traceability was approved by S&ID with the exception of two items. Traceability on these two items has been assured and no schedule slippage is expected. Beech is currently meeting the requirements of the S&ID I&T specification.

The Beech failure effects analysis of the O_2 and H_2 fill, vent and purge disconnects has been completed and submitted to S&ID. The Beech logic diagrams for the O_2 and H_2 check valves, and the heating, circulation, and control functions have been completed and submitted to S&ID.

The mission success reliability prediction, R_{MS}, obtained from the revised cryogenic storage system mathematical model, is 0.9992. This prediction reflects some changes in component evaluation.

[redacted]

[redacted]

PLANNED ACTIVITIES

The following areas will receive concentrated attention during the next reporting period:

1. Structural reliability analysis of storage vessels

2. Major design review

3. Review of subcontractor reporting and design review programs

General development testing for all previously untested components will begin.

[redacted]

[redacted]

EARTH LANDING

SUMMARY

Documentation requirements and support of other S&ID groups in areas which affect crew safety or mission success have been coordinated with Northrop-Ventura. Specific studies included the use of redundant drogue parachutes and the use of redundant reefing lines on the main parachutes (to insure reduced loading on the main chutes).

The reliability portion of the Northrop-Ventura contract was finalized during June, 1963.

S&ID personnel also participated in the accident investigation of the Boilerplate 3 failure (test 5).

FAILURE EFFECTS ANALYSIS

Updating of the earth landing failure effects analysis has been completed. This analysis is currently being revised to incorporate the dual drogue concept.

PROBLEM AREAS

Three major problems were established which degrade ELS (Earth Landing System) reliability below an acceptable level:

Main Cluster Disconnect Detonators

1. The detonators are not passing the static sensitivity requirements.

2. The results of dent block tests indicate that the output of the detonators varied excessively and that there have been some cases during which the linear shaped charge failed to detonate because of insufficient detonator output.

Pilot and Drogue Mortar Cartridges

The first samples of the cartridge used in the pilot and drogue mortar produced excessive pressure. This was caused by a misinterpretation of the specification by the supplier with reference to the total output pressure required.

[redacted]

Main and Pilot Parachute Suspension Links

Suspension link failures were experienced during bomb drops. The suspension line malfunction on the pilot parachute and the broken suspension links on the main parachute were caused by lack of control in the manufacture, contour, and finish of the link and by improper application of the link. Recommendations have been submitted for corrective action on the above problems.

TEST PROGRAM

Additional development tests are required for the dual drogue concept and for redesign of the main chute disconnect. As a result, the development test is only 40-percent complete instead of 50-percent.

The following drop tests were conducted during this report period:

Drop Test No.	Test Description	Comments
B/P 3-4	To support the Boilerplate 6 pad abort test. In this test, Boilerplate 3 was stabilized apex forward at a dynamic pressure of 40 psf. This was the first drop employing the new main chute retention flap assembly and the new main chute harness.	After drogue disconnect, pilot mortars fired at a 135-degree angle of attack. Main chute deployment resulted in blanketing of 2 of 3 main chutes. Subsequent descent was stable.
No. 42	To evaluate performance of a cluster of two PDS 2072 parachutes deployed at design dynamic pressure. Reefing line was increased to 8.5 percent.	One chute was badly blanketed by the other chute which opened very rapidly with the consequent failure of two diametrically opposed gores. The blanketed chute then opened and successfully recovered the bomb.
No. 43	To evaluate performance of a pair of PDS 2119 drogue chutes when deployed simultaneously at design dynamic pressure.	Successful
B/P 3-5	To evaluate ELS at dynamic conditions predicted for Boilerplate 6.	Failure of one pilot chute and two main chutes resulted in destruction of Boilerplate 3.

[redacted]

[redacted] [redacted]

Drop Test No.	Test Description	Comments
No. 44	Evaluate opening characteristics of dual drogue system.	Successful

The fifth drop of the Apollo Boilerplate 3 was conducted as a constraint drop task for Boilerplate 6. This test was the fourth in a series of constraint drop tests and the third test requiring recovery of the vehicle from an apex forward condition. In this test Boilerplate 3 was not recovered satisfactorily because of damage to the main parachute harness assembly which resulted in structural failure that caused two of the main parachutes to separate from this vehicle. Damage to the main harness is attributed to structural degradation of the upper harness legs by the main parachute disconnect and abrasion over the vehicle structure in the gusset areas while the boilerplate was at approximately a 90-degree angle of attack. Failure of the third main parachute to deploy properly was caused by the abrasion failure of the pilot parachute riser.

Other development test results are the following:

1. Failure of space ordnance systems cartridges occurred during testing with the drogue mortar. Tests on the redesigned cartridge are now in process.

2. Failure of the space ordnance system detonators during tests and the necessity for redesign have caused schedule slippage of boilerplate tests.

3. High reaction loads of the pilot chute mortar using the specified cartridges occurred.

SUBCONTRACTOR MANAGEMENT

During this quarter two reliability coordination meetings were held with Northrop-Ventura. Specific areas that have been clarified are the requirements for identification and traceability and the procedures for reporting all pyrotechnic failures.

Northrop-Ventura is presently evaluating and updating the main chute disconnect reliability analyses in conjunction with current design changes.

PLANNED ACTIVITIES

The following significant activities are planned for the next reporting period.

[redacted]

1. Completion of preparations for delivery of the Boilerplate 12 system

2. Completion of environmental testing of fabric materials

3. Completion of pull tests on main harness assembly

4. Completion of four drop tests of dual-drogue system

5. Initiation of wind tunnel parachute tests

[redacted]

ELECTRICAL POWER

SUMMARY

Fuel Cells

Two separate studies dealing with the performance and safety of the fuel cell have been conducted.

A comparative analysis of the proposed three-zone heating system, intended to reduce heat-up time and provide even heat distribution during the cool-down period, has been completed.

A probability analysis has been performed to establish the possibility of simultaneous leakage of reactants from the fuel cell module and associated plumbing. The study revealed a probability of this occurring in 41 chances out of one million.

Pratt & Whitney submitted a reliability-growth curve showing the achieved and the projected reliability of the fuel cell power plant, based on development test data.

Electrical Power Distribution

To determine whether any single failure will cause a mission abort, a failure effect analysis of the electrical power system has been initiated. The investigation showed that ac and dc buses in the distribution system might cause an abort in case of a potential short of considerable magnitude. However, each bus has a very high inherent reliability, and a failure of this nature is highly improbable.

Inverter

On the basis of the recent reapportionment of the reliability requirements for one electrical power system, S&ID can justify the request of Westinghouse Electric for a reasonable reduction in the present reliability goal of 0.9632 since sixty additional components had to be added to the unit to enhance the existing design.

S&ID and Westinghouse have agreed that Westinghouse will control all semiconductors and magnetic components by serialization and lot number, according to the fabrication source and process.

Hughes Connector

The inability of Hughes connectors to meet the retention force specification requirements established by S&ID has been investigated. As a result, the S&ID specification for "X" models was changed to an 8-pound retention force. Also, in order to correct the existing problem and to satisfy the specification requirement for flyable hardware, S&ID has accepted a Hughes recommendation to restrike the present retention clips, ensuring that all flanges are 30 degrees.

SPECIAL STUDIES

Fuel Cell Heating Study

The reliability analysis group has completed a comparative analysis of the three suggested three-zone heating systems intended to reduce heat-up time, compensate for the high heat losses experienced at the stack ends, and provide even heat distribution during the cool-down period. A separate power source for each zone is necessary for three-zone heating.

The three-zone heating systems considered in the analysis were the following:

1. A manually operated interlocking control system allowing the operator only three decisions for the operations: heat-up, temperature hold, and cool-down. Each decision is limited to one combination of predetermined and fixed voltage inputs to the three proposed zones of the cell stack.

2. A manually controlled system allowing the operator an infinite number of decisions for the three required operations. The number of possible voltage inputs to each of the three zones is virtually unlimited.

3. A fully automatic system which applies power to the heaters at a constant voltage and maintains the required zone temperatures for the time intervals required.

The first two systems require an operator and a definite and reproducible cell stack temperature profile. The third system eliminates both the need for an operator and the need for the temperature profile. It is operated by temperature sensors in each of the three zones. However, it introduces additional weight as well as reliability degradations associated with system complexity.

Given a definite and reproducible cell stack temperature profile, the first system provides the highest reliability and the lowest increase in weight. A four-position switch, permitting three predetermined, interlocked combinations of voltages and an OFF position, provides maximum control over the human error factor without resorting to the more complex fully automatic system. A design incorporating the basic features of the first system is currently being developed.

Single Cell Versus Power Plant Performance Study

Filling acceptance performance data were compiled for approximately 300 single-cell assemblies and the means and variances were computed. These data are now being corrected for temperature, pressure, and electrolyte concentration and will be statistically combined for prediction of power plant performance. Actual power plant performance data are now being computed to establish the correlation with the predicted values.

Hydrogen Oxygen Leakage Study

A study to determine the probability of hydrogen and oxygen leakage occurring simultaneously during the 400-hour mission has been completed. The major potential leakage points on the hydrogen side of the fuel cell are 3 hydrogen by-pass valve seals, 62 hydrogen tube and manifold fittings, and 2 hydrogen manifold seals. The oxygen side of the fuel cell has 62 oxygen tube and manifold fittings and 2 oxygen manifold seals.

The following combinations of failures can exist during the 400-hour mission:

a - Hydrogen seals with oxygen fittings
b - Hydrogen seals with oxygen manifold seals
c - Hydrogen fittings with oxygen fittings
d - Hydrogen fittings with oxygen manifold seals
e - Hydrogen manifold seals with oxygen fittings
f - Hydrogen manifold seals with oxygen manifold seals

The total probability of failure is equal to

$$Q_a + Q_b + \ldots\ldots Q_f = \sum_{u=a}^{f} Q_u$$

[redacted]

The numerical values for probability of failures Q_a through Q_f are as follows:

$$\sum_{u=a}^{f} Q_u = 37,774 \times 10^{-10} + 3,818 \times 10^{-10} + 304,444 \times 10^{-10} +$$

$$30,776 \times 10^{-10} + 30,776 \times 10^{-10} + 3,111 \times 10^{-10} = 0.000041$$

Therefore, the probability of simultaneous leakage is 41 chances in one million or a reliability of 0.999959.

Failure Effects Analysis

A study was made of the electrical power distribution to determine which single failures are capable of causing mission abort. The investigation indicated that such a failure could only occur within the a-c or d-c bus distribution system.

There is a remote possibility of a short of sufficient magnitude on either of the two d-c buses which would cause an abort during the early portion of the Apollo Mission (first 100 hours). However, each bus has such an inherently high reliability that this type of failure is considered extremely improbable. The probability of a bus failure due to a short is less than one per million missions.

During normal operation, the three fuel cells are connected in parallel to both main d-c buses. The fuel cell outputs are individually monitored for bus disconnection which may occur due to overload. During a short, a bad segment of the d-c bus could be burned off by the application of approximately 300 amps. The batteries can supply this required amperage for a short period of time. The usable portion of the bus could then continue to be utilized for power distribution.

During normal operation, one of the three inverters is active, distributing a-c power via two a-c buses. The buses are continually monitored for an overload condition and are controlled, as required, by automatic bus disconnect. The possibility of more reliable design and better isolation features permit a lower probability of less than 0.2 per million missions for an a-c bus failure due to a short.

PROBLEM AREAS

Fuel Cell

The hydrogen pump-separator has had mechanical problems which have been investigated and corrected. However, KOH (potassium hydroxide) contamination is still a problem and investigation will continue.

It has recently been determined that many cell shorts have been caused by the displacement of KOH fill tubes. An investigation is being made to determine the cause.

The maximum operating time without malfunction yet achieved by a fuel cell is 192 hours; this occurred in May. The average load time in June was 95 hours, with a maximum of 140. In July the average fell to 41 hours with a maximum of 106. The required operating life of the power plant is 400 hours.

Static Inverter

It has been established that Westinghouse experienced several significant component failures during development which were not reported to S&ID. Westinghouse has been informed of their contractual obligation to report all failures occurring during their development and qualification programs.

Storage Battery

Failures such as that occurring at the Eagle-Picher facility are to be eliminated through tighter quality control procedures. It is not expected that plate shorting failures will occur in future tests.

TEST PROGRAM

Fuel Cell

Ten power plants are now in the development phase of testing. Five of these are of PC3A2 (Apollo) configuration. Seventy-two percent of the fuel cell development tests scheduled have been completed. Qualification tests on the power plant are scheduled to begin in August, 1964. Qualification testing of the shipping container has been completed. A number of components are still in the development stage undergoing scheduled performance and endurance tests.

A life test was conducted on ten single cells to obtain a preliminary estimate of cell life. Three of the cell tests had to be suspended and one was excluded because of defects. Results of the six remaining tests were used to derive a Weibull plot of cell life. Although not completely satisfactory, an analysis of the plot yields a maximum estimate of 300 hours ±13 percent for cell life.

Causes of power plant development failures during June and July are listed below.

[redacted]

Causes	No. of Failures
Cell short or low performance	3
Hydrogen pump-separator	4
Flooding	1
Hydrogen gas leak	1
Oxygen vent line plugged	2

Electrical Power Distribution

Bids are currently being negotiated for the majority of the system components. Procurement specifications have been released in most cases, but contract verification awaits final evaluation of bidders' proposals. In the case of major components, testing is in the development stage.

Static Inverter. Development tests are in progress. Qualification tests are scheduled to start 1 May 1964 and terminate 15 December 1964.

A vibration study has been completed in the development of the static inverter. All severe resonances within the inverter were damped or eliminated through design modification.

Testing of a thermal mock-up was completed and booster stage transistors have been relocated to permit operation in a low-temperature environment and to make use of improved heat dissipation areas. Thermal conducting resin similar to that used on the inverter has successfully withstood levels of temperature and vibration which are beyond specified limits.

Battery Charger. Development tests have been completed. Qualification tests have not yet been scheduled.

RF interference tests were conducted on the new engineering model prototype. The unit did not meet specification requirements on RF interference although the a-c and d-c inputs were satisfactory. Environmental tests, including vibration, were completed on development units.

Storage Battery. Development tests are in progress and scheduled for completion in October 1963. Qualification tests are scheduled to start in October 1963.

A total of thirty current-drainage tests at the Eagle-Picher facility and ten in-house performance tests have been completed. One significant failure occurred at the supplier's facility, which could be attributed to deficient quality control procedures.

[redacted] [redacted]

SUBCONTRACTOR MANAGEMENT

Reliability Growth Curve (Pratt & Whitney)

At the request of S&ID, the subcontractor has prepared an estimated reliability growth curve (Figure 2-1) indicating the projected fuel cell reliability as well as estimated power plant reliability based on the data in Table 2-4.

Table 2-4. Test Data, Power Plant Reliability

Test Information	Point One (15 Oct 1962—15 Feb 1963)	Point Two (15 Feb 1963—15 May 1963)
No. of tests	2	9
No. of successes	0	4
No. of failures	2	3
No. of exclusions	0	2
Accumulated test time (hrs)	27	835
Projected test duration (hrs)	50	100
Average test duration (hrs)	13	119
Estimated reliability	2.8%	58%

In the future S&ID will forward NASA an updated copy of the reliability growth curve as soon as it is available.

Hughes Connector

S&ID was notified, along with other Apollo users of the Hughes connector, that the specification retention force of 15 pounds could not be met in specified lots. This problem was caused by undersized retention clips, which were not inspected and were being assembled on the contacts and pins. S&ID investigated this problem at the Hughes facility and found that a stock strip guide on the progressive die moved from its setup position, which in turn produced undersized retention clips.

It was also determined that users of this connector were experiencing various assembly problems. A three-man team representing S&ID and Hughes was sent to review subcontractor connector problems and initiate and recommend corrective action. It became apparent that in order to assure reliable assembly of this subminiature connector, various aids would be required such as assembly procedures, inprocess inspection points, tool calibration procedures, and employee training.

[redacted]

[redacted]

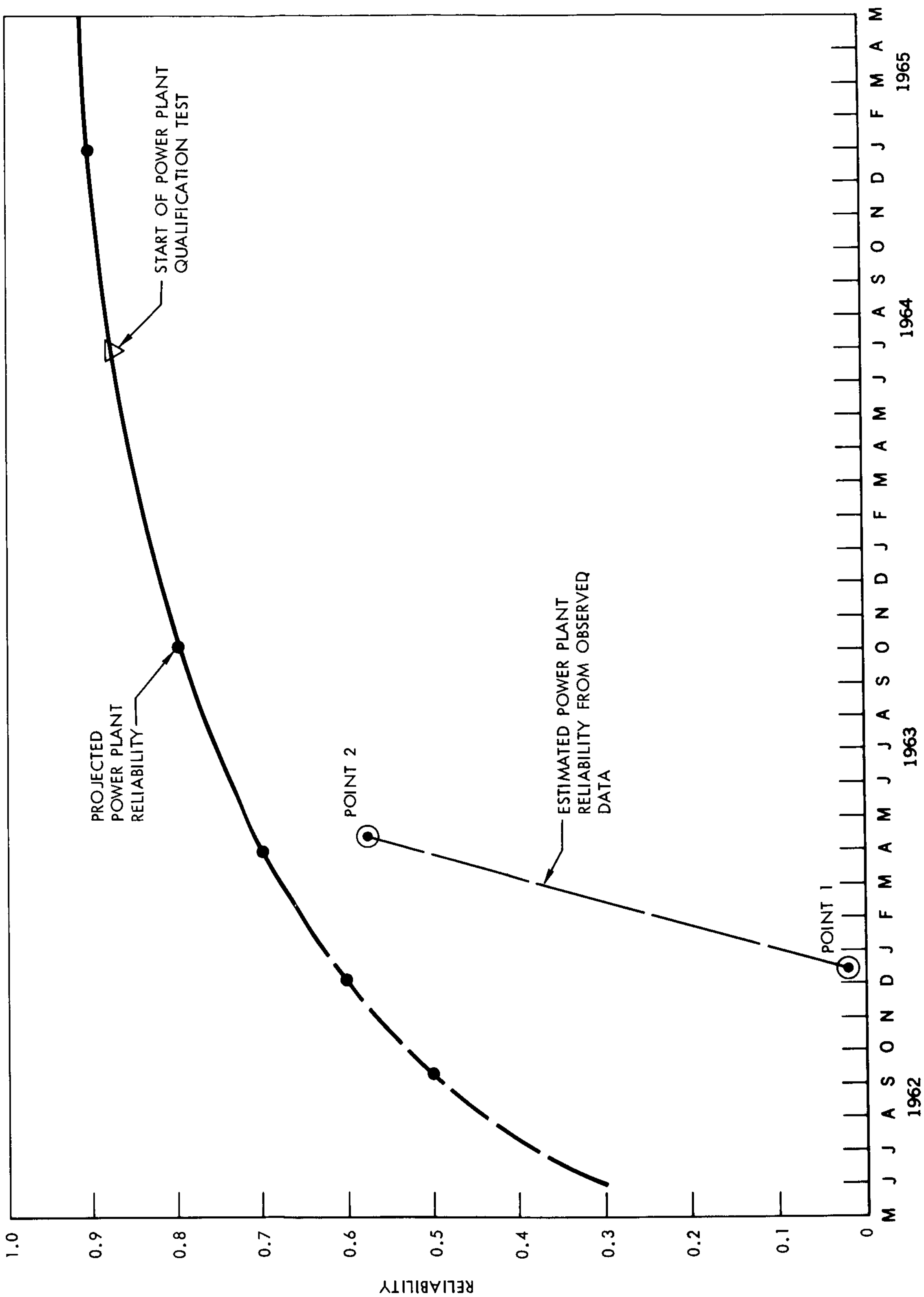

Figure 2-1. Apollo Fuel Cell Powerplant Reliability Growth

[redacted]

The next major problem occurred at Minneapolis-Honeywell, where pins having retention clips, as specified by the blueprint, were also failing to meet the 15-pound retention force. Minneapolis-Honeywell sent two representatives to Hughes with their own tools, connectors, pins, and inspection equipment to demonstrate the problem at the Hughes facility. During the first two days of testing, M-H could not demonstrate the problem using both M-H and Hughes retention force test equipment (after 10 insertions and removals at a retention force of 15 pounds). However, 3 failures did occur on the third day after more than 70 tests.

Hughes was then requested to devise a solution and recommend a recovery program in order to minimize schedule slippage throughout the program. Simultaneously, S&ID reviewed the specification for a possible reduction of the required retention forces for nonflyable hardware only. S&ID investigation of similar types of connectors indicated that S&ID specified retention forces for the size 22 pin and contacts were more stringent than were generally available in industry:

S&ID: Size 22, 15 pounds after 10 insertions and removals

Amphenol: Crimp removable contact, 22-28 solid wire, 24-26 stranded wire, 10 pounds or 5 pounds after 10 insertions

Deutsch: DSM line, Size 20 (for comparison), 15 pounds after 10 insertions

Cannon Electric: Size 20 contacts, 5 pound minimum with up to 100 insertions.

As a result of this investigation and the reliability recommendation, the S&ID specification for X models only (for nonflyable hardware) was changed to 8-pound retention force.

Hughes presented their plans for corrective action and recovery. The Hughes analysis provided three possible solutions to the retention problem:

1. Change of connector body material and length of fiber

2. Change pin and contact material from leaded copper to half-hard brass

3. Restrike retention clips to ensure that all flanges are 30 degrees

Restriking the retention clip was found to be the best solution to the problem. Testing continues at Hughes to establish the satisfactory reliability of this solution.

[redacted]

Westinghouse Inverter

Westinghouse estimates the latest reliability prediction for the inverter to be 0.9596, based on a mission time of 336 hours. This is a considerable decrease over the previous reliability estimate of 0.9632 and is due primarily to sixty additional components which were incorporated to enhance the design. The original apportioned reliability goal for the inverter was 0.9786. Westinghouse recently requested a deviation to 0.9596, claiming that this value is the highest attainable. Moreover, a recently completed apportionment analysis by S&ID indicates that a reliability goal of 0.9596 for the inverter is realistic to meet the over-all electrical power system reliability requirement.

The sixty additional components were incorporated to improve the efficiency of the lagging power factor and the stability of the main power stage, especially for a half-wave load, and to improve the pilot oscillator for the booster state. Forty of the 60 components are considered series items, i.e., the failure of any of the forty components will cause the inverter to fail. Twenty of the sixty components are redundant; a failure of any one of these will not cause the inverter to fail. The diode redundancy incorporated to keep the failure rate of the inverter to a minimum is illustrated as follows:

SINGLE DIODE	R = 0.999
DIODE REDUNDANCY	R = 0.999999 (Primary mode of failure for a diode is a short)

It was mutually agreed at a monthly coordination meeting that Westinghouse would control all semiconductors and magnetic components by serialization and lot number from the manufactured source and process. Serialization of individual parts from controlled lots would permit traceability with respect to parametric or associated test data. All other components (e.g., resistors, capacitors, etc.) will be lot controlled by the manufacturer to the manufacturing process.

PLANNED ACTIVITIES

Fuel Cell

During the next quarter power plants will undergo vacuum endurance, vibration, sea-level endurance, and start tests. Development tests of all components will continue.

[redacted]

Static Inverter

Activities will be limited to performance testing of various unqualified units. Qualification tests are scheduled to start 1 May 1964. The development test phase is approximately 96 percent complete.

Battery Charger

Qualification test schedules are due from ITT on 1 October 1964. The development test phase is complete. Further test activities are curtailed pending receipt of component parts needed to fabricate test units.

Storage Battery

Development tests are 98 percent complete. The next planned test activity is the qualification test phase which is due to start about 15 October 1963.

Other Electrical Components

Suppliers for most of the components are in the process of determination or have recently been selected. In either case the development tests will be initiated or continue for the next quarter.

[redacted]

ENVIRONMENTAL CONTROL

SUMMARY

Special studies were conducted to determine the effects of design changes on reliability and to determine if the present design is adequate to meet reliability goals. Other activity included participation in design review activity at the AiResearch facility.

Development testing is in progress on 85 percent of the ECS components. Over-all component development testing is 75 percent complete. Qualification tests will begin 15 November 1963. Development testing continues on the single cold plates. Seventeen coldplates of nine different categories have been received, and general development testing will begin on all of these. The approximate qualification testing date is 15 November 1963. Phase I design verification testing continues on space radiators. Qualification testing will start 7 October 1963.

SPECIAL STUDIES

Proposed ECS Changes

Reliability studies were performed on the following proposed ECS design changes:

1. Deletion of manual shut-off valve 2.28 which is a backup for the cabin heat exchanger water-glycol check valve 2.5.

2. Deletion of bypass line and manual shut-off valve 2.28, which provides water-glycol pump bypass during ground servicing. An accompanying change would be deletion of the manual shut-off valve 2.28 at the glycol pump's inlet.

3. Deletion of the water tank pressure relief bypass line and redundant check valves.

4. Deletion of the water fill ground servicing connection and line in the SM.

5. Deletion of entire Freon system. Glycol would be cooled prior to launch to provide a heat sink during launch.

[redacted]

6. Deletion of three-way solenoid valve in radiator circuit and addition of open-closed solenoid valve in ground servicing return line.

All the above changes were approved from a reliability and crew safety standpoint except for item 3. This change was not approved; if the bypass line and check valves were deleted and a requirement arose during the mission for valve 5.19 to be closed and the potable water system to be subsequently filled, then the fuel cells would be flooded and rendered useless. The assumption is made that the crew might forget to open valve 5.19 when the potable system is filled, which could occur during C/M operation by a single individual.

ECS Component Packaging

The following three design concepts of component packaging for the ECS water management control panel were evaluated:

1. Eight components (valves, relief valves, and check valves) connected by tubes and flare type fittings (present design).

2. Components connected by tubes, brazed connections, and slip-joints.

3. Integrated manifold mounting of components with brazing of tubing where required.

Because it would eliminate most of the flared tube fittings, the integrated manifold concept was recommended. Subsequently, the cognizant S&ID group approved this concept for use in the ECS.

ECS Water-Glycol Circuit

Several reliability studies on the ECS water-glycol circuit were conducted for presentation to NASA. These studies demonstrated that the present design concept of two water-glycol pumps with redundancy and manual override capability of critical components in the water-glycol circuit approaches the required reliability necessary to achieve the ECS goals. These studies were presented to NASA during monthly ECS coordination meetings.

ECS Instrumentation Analysis

A reliability analysis of ECS instrumentation was performed during the report period. The analysis indicated that the instrumentation for the

[redacted]

ECS is not adequate from the standpoint of numerical reliability. As a result, the following recommendations have been made:

1. Use of redundant sensors in all applications.

2. Improvement of the inherent reliability of all readout devices.

3. The use of telemetering for standby readout wherever possible. Telemetering will not improve the sensor function, but it will enhance the readout function.

Incorporation of the above recommendations is being investigated by cognizant S&ID groups.

PROBLEM AREAS

1. The CO_2 and odor absorbing canisters are presently being assembled; a few problems have developed with the cover seals.

2. The glycol evaporator distribution system is presently being redesigned to incorporate a brazed assembly to replace an Epoxy seal which would not withstand the thermal expansion characteristics of the dissimilar metals.

3. A prototype O_2 mass flow transducer was tested at ambient temperatures of 0 F and 200 F, and with oxygen flow at 0 F. The output of this unit exceeded the allowable tolerances.

4. Glycol temperature control tests were conducted to evaluate the mode of mixing operation at various initial glycol temperatures. Cycling instability was observed at various pump inlet temperatures.

5. Earlier tests using the ECS development system demonstrated that gas in the glycol circuit could cause flow stoppage. Tests were planned to evaluate the effects of water-glycol aeration and to attempt to determine the de-aeration level required for acceptable ECS operation. A transparent pump assembly was installed in a test loop using transparent lines. Bubbles formed on the upstream side of the filter and entered the impeller. (De-aerated water-glycol was used.) Gas occupied 90 percent of the volume between the filter element and housing, causing the glycol flow to stop. Gas in the filter housing did not redissolve. Chemical analysis of the gas bubbles gave no evidence of glycol breakdown. Complete evacuation of the test loop did not prevent

bubble formation. The laboratory method of de-aerating the water-glycol test fluid proved inefficient. Glycol pumps are sensitive to orientation in a 1-g field.

6. Three eutetically bonded coldplates were successfully leak checked with helium; however, wrinkles were apparent in the cover sheets over some of the lightening cavities, and total flatness was not maintained within tolerance. These problems are being corrected.

7. There has been a small maldistribution of flow between the No. 2 and 3 tube panels. The flow test results differed slightly from those originally calculated. However, the panel is a good heat exchanger.

TEST PROGRAM

Eight glycol pump assemblies utilizing journal bearings are undergoing endurance testing with no degradation in performance. Two of the pumps have withstood 1870 hours of endurance testing.

A temperature control has withstood 1066 hours of endurance testing without degradation of performance.

The back pressure control system was installed in the glycol evaporator subsystem, and initial calibration was performed. The system functioned properly, but further control calibration is required.

A preliminary test was made to evaluate the water retention capability of the evaporator wicks under gravity, with the water inlet on the top of the evaporator. Water carryover into the steam duct was observed. With the evaporator inverted from the previous position (water flow up through the wicks), water carryover was minimized.

The glycol fill and vent connection was subjected to 100 connect and disconnect cycles with the GSE coupling to verify the abrasion strength of the "O" seal. The unit was also subjected to a temperature shock test from -250 to +250 F. All test results were satisfactory.

The demand pressure regulator is presently undergoing vibration testing. The unit has shown satisfactory performance under vibration scan, scan at altitude or emergency operation, and brief time dwell at resonant frequencies.

The potable water supply assembly has satisfactorily completed high- and low-temperature tests, a leak test, and a 13-day humidity test.

A modified version of the O_2 supply check valve in the 100-psi oxygen system was tested at 1500 psig. Satisfactory results show the feasibility of using existing design concepts for high-pressure applications.

Endurance testing of the cabin recirculating blowers is being conducted on two development components that currently have an average operating life of 4165 hours.

The regenerative heat exchanger portion of the suit heat exchanger has been deleted from the heat transfer unit. The cabin heat exchanger has undergone a heat transfer test and has met the test with a sufficient margin of safety.

Three different models of development temperature sensors were subjected to a 78-g shock test in all three axes with no malfunction or damage at the conclusion of each shock.

One prototype cold plate has successfully completed inspection, proof pressure, leakage, pressure drop, thermal gradient, thermal conductivity, and pressure cycling tests.

A full-size, roll-bond radiator panel complete with bonded honeycomb and inner face sheet to simulate the spacecraft configuration was instrumented, coated with inorganic paint, and placed in the space chamber awaiting final hook-up prior to formal testing to determine pressure drop and flow distribution characteristics.

Pressure drop and temperature changes were investigated on a full-size radiator panel using ethylene glycol solution according to AiResearch specification. The panel is coated with ARF TC 50-11 organic coating.

SUBCONTRACTOR MANAGEMENT

ECS Design Review

S&ID representatives participated in the AiResearch in-house design reviews of some of the environmental control system components. Several suggestions were made on the suit bypass valve, cabin pressure regulator, and cabin relief valve as follows:

1. A 30-micro finish should be specified on all sliding or rotating valve stems.

2. Dry Lubriplate should be included on all friction surfaces.

3. Valve position indicators should be incorporated.

4. Positive stops should be provided where manual override operation could damage delicate actuator parts.

5. A choice should be made between a manual knob or a remote driving coupling.

6. Break-away pressure requirements for synthetic valve seats should be reviewed.

AiResearch set up a development canister to demonstrate crew operation, mechanical linkage, and safety interlocks for the carbon dioxide and odor absorber package. The following discrepancies were pointed out during the review.

1. The handle that releases the canister door does not allow enough clearance for the suit glove.

2. If the diverter or check valve leaks, it will be impossible to use the CO_2 and odor absorber unit. A manual interlock override was suggested.

3. There is no means for indicating which odor package requires replacement.

4. Refinement of the door operating mechanism is required to assure that the closing force is within crew capability.

5. Urine could accumulate in the suit during preflight and boost. If entrained in the suit circuit atmosphere, it will pass through the odor absorber package and react with the LiOH, leaving corrosive deposits, which could make the absorber ineffective.

No action on the above items is contemplated at this time, since any requirement for AiResearch to incorporate these changes must be a result of S&ID direction.

Component Design Reviews

During the reporting period design reviews were conducted on the following components:

Item	Part No.	Description
1.8	811100-1-1	Debris trap
2.1	827990	Glycol check valve

Item	Part No.	Description
2.5	827990	Glycol check valve
2.6	812000-2-1	Glycol evaporator
2.24	827060	Glycol fill valve
2.28	827050	Glycol shutoff valve
3.2	812100-2-1	Cabin heat exchanger
4.16	827330	Demand regulator
4.17	827310	Oxygen supply valve
4.22	827550	Emergency inflow regulator
4.24	927330	Oxygen pressure regulator
5.1	827520	Water quick disconnect
5.5	827930	Water control valve
5.14	812400-2-1	Water chiller
5.18	827410	Water shutoff valve
5.19	827970	Water pressure relief and shutoff valve
5.28	827940	Freon quick disconnect

Failure Mode and Effects Analysis

A failure mode and effects analysis was performed on the components of the ECS water-glycol circuit during this report period. The analysis was performed in accordance with the AiResearch report for the present ECS configuration. The remaining loops will be completed in the following order of priority:

Pressure suit circuit
Oxygen supply
Water supply system
CM pressure and temperature control system

[redacted]

PLANNED ACTIVITIES

During the next report period, subcontractor activities will be directed and monitored, special reliability design studies will be performed and failure effects analysis and logic diagrams will be updated as required to reflect design changes to the ECS.

The planned test activities for the next quarter are as follows:

1. General development testing will continue on all untested components.
2. Qualification testing is scheduled to begin 15 November 1963.
3. The potable water supply valve assembly is scheduled for vibration testing.
4. The first carbon dioxide and odor absorber canister will undergo development testing.
5. The cabin heat exchanger is scheduled for vibration and mechanical shock testing.
6. Insulating material will be installed on the first unit of the water chiller, which has been fabricated; general development testing will begin.
7. A dummy space radiator panel has been sent to the Los Angeles division and will undergo vibration and acoustic testing.
8. The analysis study of space radiator coatings, which is still in progress, will continue.
9. The in-house single cold plate will undergo vibration testing upon completion of the test fixture. After vibration testing, it is scheduled for acoustical, acceleration, shock, and rupture tests.

[redacted]

LAUNCH ESCAPE

SUMMARY

Particular effort was devoted to surveillance of the propellant cracking problem associated with the launch escape motor. Coordination with this subcontractor was maintained on a continual basis in order to evaluate study progress. All significant experimentally designed tests associated with the moisture problem were observed by S&ID personnel. Test data and results were continually evaluated to determine over-all effect on motor reliability.

Initial effort associated with the implementation of the identification and traceability requirements was completed. Review, analysis, and coordination concerning subcontractor identification and traceability programs are to continue as required.

PROBLEM AREAS

A propellant grain temperature rise of about 70 F during resonant dwell vibration testing of a tower jettison motor was observed. It has been proposed that this motor and one other motor be subjected again to resonant dwell vibration and random vibration simulating flight conditions. This testing will complete the development phase. Another problem experienced was large pressure spikes upon initiation of the pyrogen units utilizing hot wire initiators. Examination of these units after testing showed loss of hardware due to shock damage to the boron pellet basket. Thiokol is investigating this problem during tests utilizing hot wire igniters of modified propellant charge and modified propellant mix.

A total of five launch escape motors subjected to temperature cycling tests by the Lockheed Propulsion Company exhibited grain cracking due to surface weakening of the grain as a result of moisture collecting within the propellant cavity. Lockheed asserts that propellant grain cracking was due to external moisture entering unsealed motors while they were being temperature cycled, and moisture entering the motor during visual inspections performed after temperature cycling. New procedures to avoid this problem are being developed, and an igniter wrap-around type desiccant pack is being obtained.

[redacted]

Inasmuch as existing data indicates that moisture degrades propellant strength and because inspection of the failed motors revealed the presence of water on the propellant grain surface, the investigation placed emphasis on determining the sources of moisture. Laboratory and special tests indicated that the propellant grain is not an important source of moisture. As a result of these investigations, four additional motors were assigned to the development program to partially replace the motors lost due to the grain cracking problem and to provide full-scale verification of the cause of the problem. Three of these motors were tested under revised procedures. The fourth was temperature cycled for two cycles under the revised procedures, and then was cycled under the procedures in effect during the period of grain cracking.

Investigation into the method of scaling the temperature cycled motors revealed that unsealed motors accumulated large amounts of moisture on the grain surface, but that positive sealing of the motors prevented the accumulation of moisture.

Steel plate from U. S. Steel received by Lockheed exhibited indications of porosity and inclusion which could possibly make it unsuitable for welding. Consequently, it was decided that this steel plate should not be used for launch escape motor cases. New shipments from U. S. Steel will take about 8 weeks. This will result in about a 4-week slip in the qualification schedule of the launch escape and pitch control motors.

TEST PROGRAM

The Apollo General Test Plan, SID 62-109, was revised during the last quarter. The first launch escape motor wire fired using the low voltage hot wire initiators. The first development firings of igniter cartridges were conducted at Space Ordnance Systems. Thiokol experienced failures during the qualification burst tests of the motor core as a result of the 260,000-psi tensile-strength bolts failing below the specified motor case design burst pressure. After conducting 11 hydroburst tests on the 260,000-psi tensile-strength bolt, Thiokol is returning to the use of the 220,000-psi tensile-strength bolt based on successful results during a total of five hydroburst tests utilizing this bolt. Initial reliability assessments based on development test results were accomplished by the supplier in addition to more complete failure mode analyses.

The tower jettison motor has demonstrated a reliability of 0.79 at a 90-percent confidence level and 0.90 at a 50-percent confidence level, based on test results for 17 such motors (including one failure).

[redacted]

The reliability demonstrated by 25 pitch control motor tests is 0.973 at a 50-percent confidence level, using the binomial technique of analysis of qualitative parameters.

The pitch control motor development program was completed 23 July 1963. The completion of the launch escape motor development program was delayed due to additional testing required as a result of a moisture and grain cracking problem. Two development motors remain to be fired in order to complete the launch escape motor development program. The completion of the tower jettison motor development program was delayed because of additional development testing required as a result of a temperature rise problem experienced during vibration, low-burst pressure of the motor case, and loss of hardware during pyrogen ignition. Two development motors also remain to be fired in order to complete the tower jettison motor development program.

SUBCONTRACTOR MANAGEMENT

Briefing on subcontractor and supplier identification and traceability requirements (I & T) was provided Lockheed Propulsion Company personnel. The briefing consisted of a general description of I & T and a question and answer session concerning MA-0201-0209A, "General Specification for Apollo Program Subcontractor and Supplier Identification and Traceability."

PLANNED ACTIVITIES

The firing of two launch escape motors and two tower jettison motors will complete the development phase for the launch escape system. This will occur during the next quarter. Initiation of qualification testing for the launch escape system should occur within the next quarter, assuming successful resolution of current development test problems.

Construction of the Apollo test bay is continuing and is expected to be completed in time for the initiation of qualification program testing currently scheduled for November 1963.

[redacted]

SEPARATION

SUMMARY

The status of the separation systems remained unchanged during the preceding quarter, with the exception of the launch escape tower separation system. The system has been changed to incorporate a tower flap, which eliminates the apex forward attitude at forward heat shield cover jettison and drogue deployment.

ANALYSIS

Eight dual mode bolts and four passive tension ties are used on the launch escape tower separation system. For low-altitude aborts, below 30,000 feet, the tower jettison motor pulls the heat shield cover off with the four passive tension ties, and the drogues pull the command module around.

For aborts above 30,000 feet, four dual mode bolts located at the aft end of the structural skirt separate the launch escape motor from the tower which houses the flap. At forward heat shield jettison, four dual mode bolts separate the tower from the command module structure and four thrusters, each of which breaks an internal tension tie, separate the cover from the command module. The four thrusters jettison the cover with attached tower away from the command module. The additional dual mode bolts required for the tower flap provide an over-all increase in subsystem mission reliability. This increase is due to the elimination of the undesirable apex forward condition at heat shield jettison, which was characteristic of the earlier design.

TEST PROGRAM

With the exception of those tests for which the start and completion dates have been revised as shown in Table 2-5, the development test schedule in Table 2-31, SID 62-557-6, remains in effect.

No qualification tests were completed during this period.

[redacted] [redacted]

Table 2-5. Development Tests (S&ID)

ATR No.	Title of Test	Start Date	Completion Date
100A	Separation System: CM from SM	April 1963	March 1964
101	Separation System: SM from S-IV Adapter	September 1963	October 1964
102B	Separation System: Escape Tower from CM	May 1963	April 1964

Test Status of Pyrotechnic Devices

Table 2-6 summarizes the test results for all pyrotechnic devices and systems, updated to 30 September 1963.

Development Tests

Development tests begun or still in progress are shown in Table 2-7. Table 2-8 shows development tests which have been completed.

PLANNED ACTIVITIES

Development tests of the following pryotechnic devices will be in progress during the next report period:

1. Pressure cartridge, forward heat shield separation system (redesigned)
2. Explosive bolt, dual mode, tower separation system
3. Detonator, CM to SM separation system

Qualification tests of the standard hot wire initiator are expected to be completed during the next report period.

[redacted]

Table 2-6. Test Status of Pyrotechnic Devices*
Summary of Test Results to September 20, 1963

Ref No.	Component or System	Supplier	Tests to Date Total	Tests to Date Fail	Usage
1	EBW initiator (pre-disc)	Aerojet	*450	*8	BP 6 only
2	Standard hotwire initiator	Space Ordnance Systems	*511	*50	All BP and SC
3	Pressure cartridge type I	Space Ordnance Systems	0	0	All BP 12 and subsequent
3	Pressure cartridge type II	Space Ordnance Systems	0	0	All BP 12 and subsequent
3	Pressure cartridge (forward heat shield)	Space Ordnance Systems	0	0	All BP 22 and subsequent
3	Detonator cartridge	Space Ordnance Systems	0	0	All BP and SC
3	Igniter cartridge	Space Ordnance Systems	0	0	BP 12 and all subsequent
	Explosive bolt, single mode	Space Ordnance Systems	55	0	BP 6 only
	Explosive bolt, dual mode	Ordnance Association	0	0	BP 12 and all subsequent
	Sol-2-314 hotwire initiator	Space Ordnance Systems	126	0	BP 6 only
	Linear-shaped charge	To be determined	0	0	To be determined
4	Drogue chute disconnect	SID	15	2	BP 6 only
	Main chute disconnect	Northrop-Ventura	0	0	BP 6 only
	Drogue chute mortar	Northrop-Ventura	0	0	All BP and SC
	Pilot chute mortar	Northrop-Ventura	0	0	All BP and SC
	Tower separation system	SID	7	0	BP 6 only
	CM to SM separation system	SID	0	0	BP 12 and subsequent SC
	Adapter separation system	SID	0	0	BP 18 and subsequent SC
	Umbilical disconnect	SID	0	0	AFRM 9 and subsequent SC
	Circuit interrupter	Ordnance Association	0	0	AFRM 9 and subsequent SC

[redacted]

[redacted]

Table 2-6. Test Status of Pyrotechnic Devices*
Summary of Test Results to September 20, 1963 (Cont)

Ref. No.	Component or System	Supplier	Tests to Date Total	Tests to Date Fail	Usage
	Launch escape motor ignition	Lockheed Propulsion	11	1	BP 6 only
1	Pitch control motor ignition	Lockheed Propulsion	23	1	BP 6 only
1	Tower jettison motor ignition	Thiokol	17	0	BP 6 only
	Tower separation system	SID	0	0	BP 12 and all subsequent
	Forward heat shield separation system	SID	0	0	BP 22 and all subsequent
	Drogue chute disconnect	SID	0	0	BP 12 and all subsequent
	Main chute disconnect	To be determined	0	0	BP 12 and all subsequent
	Launch escape motor ignition	Lockheed Propulsion	1	0	BP 12 and all subsequent
	Pitch control motor ignition	Lockheed Propulsion	5	0	BP 12 and all subsequent
	Tower jettison motor ignition	Thiokol	5	0	BP 12 and all subsequent
	Squib valve, helium, RCS, CM	Pelmec	0	0	BP 22 and subsequent
	Squib valve, propellant, RCS CM	To be determined	0	0	BP 22 and subsequent
	Squib valve, nitrogen, ECS	To be determined	0	0	AFRM 9 and subsequent
	Drogue chute mortar cartridge	Ordnance Association	Not known		BP 6 only
	Pilot chute mortar cartridge	Ordnance Association	Not known		BP 6 only

* Total (including all applicable tests listed as well as tests on single items)

Reference 1. Failures were caused by use of "leakers" which had desensitized after absorbing cleaning solvent, or by insufficient power supply to the EBW firing unit.

Reference 2. Forty-seven failures were inadvertent firings in static sensitivity tests during the development program.

Reference 3. No tests have been performed with these devices in their final configuration.

Reference 4. In one test firing of the drogue disconnect, incomplete severance of the tension plate occurred. In the other failure listed, both detonators fired but failed to ignite the linear-shaped charges.

[redacted]

Table 2-7. Tests in Progress

ATR No.	Spacecraft Location	Title of Test	Start Date	Completion Date
105-4	Mechanical devices	Impact attenuator return motion snubber-friction	March 1963	December 1963
201	Command Module	Landing impact stability land and water	November 1962	February 1964
203A	Command Module	Model test-landing impact and stability	November 1962	December 1963
205	Command Module	Vibration and acoustic tests of typical CM panels	January 1963	December 1963
209-1 and 2	Command Module	CM aft compartment heat shield tests	April 1963	May 1964
210-1 and 2	Command Module	CM side wall structural tests	May 1963	April 1964
211-1 and 2	Command Module	CM apex structural tests	April 1963	February 1964
211-3	Command Module	Sealing of airlock components	June 1963	November 1963
211-5	Command Module	Main longern to parachute typical	January 1964	February 1964
213	Command Module	CM meteoroid shielding	May 1963	December 1963
206-1	Service Module	Vibration and acoustic tests of typical SM panel sections	December 1962	January 1964
301-8	Service Module	SPS main propellant tank cover door	August 1963	December 1963

[redacted]

[redacted]

Table 2-8. Development Test Results

ATR No.	Title of Test	Development Tests Completed	Results
105-3	Impact attenuation system complete. Test strut return snubber mechanism	2 test samples	Both failed due to non-constant cutting loads
301-12	Structural Comp. Test SM Outer shell panel blind river joint tests	3 test specimens Limit load test	One failed at 50 percent of limit load in shear, one failed at 140 percent of limit load in bending and shear, one failed at 200 percent of limit load in tension
500	Launch escape tower static structural test	Ultimate load test	Skirt and rivets failed at 140 percent of ultimate load
107-1	Gear loading test astro sextant door	Ultimate load test	Fixture failed after exceeding calculated ultimate load
107-2	Wobble gear test astro sextant door	Limit load test	Input shaft froze to input gear when gear teeth failed

[redacted]

[redacted]

SERVICE MODULE REACTION CONTROL

SUMMARY

The subcontractor's achievement of the allocated SM RCS engine reliability goal is considered a definite possibility even in view of recent development problems. The following activities are planned to ensure this achievement:

1. The following safety margin analyses will be conducted utilizing the results obtained from recent test:

   a. Pressure limitation of the combustion chamber as compared to the expected operating conditions.

   b. Correlation of the disilicide coating chamber life for the following variables:

      (1) Thickness of coating.

      (2) Expected operating conditions.

      (3) Temperature cycling limitation.

2. Additional instrumentation accuracy studies will be conducted to clarify the apparent test discrepancies between ATL and Cell 6, and the approach to be taken in complying with S&ID accuracy requirements.

S&ID personnel observed a preliminary demonstration of the actual operation of the Giannini gaging technique on 20 September 1963. Some of the equipment used in the demonstration varied both in appearance and performance from the respective counterparts in the final configuration. However, the demonstration was considered to be a valid representation of the functional operation of the system.

A coordination meeting was held at Bell Aerospace Company, the supplier selected for the positive expulsive tanks. The purpose of this meeting was to define reliability program requirements.

[redacted]

[redacted]

PROBLEM AREAS

Marquardt experienced two significant development failures during the first part of June (Table 2-9), which resulted in the fragmentation of the combustion chambers. A special reliability and engineering coordination meeting between S&ID and Marquardt was subsequently held. The purpose of this meeting was to discuss the failure analysis report for chambers SN-010 and SN-014. As a result of the above discussion and the occurrence of additional failures (Tables 2-9 and 2-10), it was agreed that the formal report should be delayed in order to include more detailed information.

Table 2-9. Chamber Fragmentation, Chamber Run History

Chamber	Engine	No. of Starts Before Failure	Total Burn Time Before Failure in Seconds	Failure Date
X19871 S/N010	T8310 S/N0001-2 8 on 8 fuel cooled	143	944	7 June 1963
T7318 S/N014	T8310 S/N0001-3 8 on 8 fuel cooled	236	769.4	10 June 1963
X19871 S/N024	X19900 S/N0007 12 on 12	3	26	7 August 1963

Table 2-10. Chamber Burn-Throughs, Chamber Run History

Chamber	Engine	No. of Starts Before Failure	Total Burn Time Before Failure in Seconds	Failure Date
X19871 S/N022	X19900 S/N0003	70	205.4	Chamber Blistered 10 July 1963
X19871 S/N030	X19900 S/N0004	6091	818.5	12 July 1963
X19871 S/N036	X19900 S/N0004	563	870.4	24 July 1963
X19871 S/N039	X19900 S/N0001	51	112.4	5 August 1963

Because of the seven significant failures outlined in Tables 2-10 and 2-11, NASA, S&ID and Marquardt held a technical conference on 9 and 10 September 1963 at Marquardt Corporation. The conference was concerned with the SM RCS engine chamber burn-through during mission duty cycle maneuvers and chamber fragmentation during ignition phase.

The following information based on tests and analyses was presented at the conference:

1. Chamber burn-throughs

   a. All burn-throughs have occurred when pressures and temperatures were conducive to vaporization or boiling in the valve and head assembly.

   b. High-speed movies of combustion phenomena show apparent loss of oxidizer boundary layer cooling.

   c. Modification of oxidizer flow passages and valve isolation have reduced critical wall temperatures.

2. Chamber fragmentation

   a. Test experience indicates that the failure mechanism is an accumulation of propellant, proportional to ignition delay, with subsequent rapid deflagration.

   b. The resulting pressure peaks caused by the deflagration of the propellants have been experienced over valve timing differences of -20 to +20 milliseconds between fuel and oxidizer.

   c. The testing indicated that the magnitude of the pressure peaks is a function of many factors including the ignition sequence, type of fuel, and propellant temperatures.

Marquardt proposed the following action to eliminate the possible recurrence of the above types of failure:

1. Chamber burn throughs

   a. Modification of oxidizer flow passage to decrease the amount of vaporization.

   b. Further investigation to improve injector flow distribution.

[redacted]

2. Chamber fragmentation

    a. Strengthen walls of cylindrical part of thrust chamber.

    b. Implement chamber dynamic pressure proof testing inspection techniques.

    c. Modify design to minimize ignition delay.

SUBCONTRACTOR MANAGEMENT

Three monthly reliability coordination and progress meetings were held between S&ID and Marquardt to review the nature and scope of the Marquardt reliability effort. The agendas for the above meetings were prepared by S&ID, and the following general items were discussed:

1. A review of the status of the reliability activities with respect to schedule and applicability.

2. A review of the nature and scope of both completed and proposed activities to determine the adequacy of the effort.

The most significant items covered during the above meetings were:

1. Instrumentation accuracy.

2. The apparent test cell discrepancies.

3. The fragmentation of the combustion chambers.

The numerical reliability requirements for the propellant gaging system have been revised. Investigation and coordination with Giannini indicated that full advantage was not being taken of the inherent redundancy of the basic design. The present requirements are as follows, both for testing purposes and for the individual portions of the system:

1. For reliability purposes, a system will be considered to be composed of the sensor units for one quadrant and the complete computer and display network.

2. The system will have a failure probability no greater than 2919×10^{-6} for 336 hours.

[redacted]

3. In order to satisfy system requirements, the individual portions of the system will have the following characteristics:

   a. Sensor/Quad. The portion of the system associated with an individual quadrant will have a failure probability no greater than 2553×10^{-6} for 336 hours.

   b. Computer and display network. The entire computer and display portion of the system will have a failure probability no greater than 366×10^{-6} for 336 hours.

Coordination meetings were held between S&ID and Bell Aerospace Company reliability personnel on 27 and 28 August 1963. The major portion of the meeting was devoted to clarification of the type of reliability program required of Bell and the degree of effort needed in the individual areas of the program. The Bell management generally agreed to implement an adequate reliability program and made commitments to this effect.

TEST PROGRAM

Information was supplied for inclusion in the Ground Qualification Tests volume and the Acceptance Tests volume of the revised Apollo General Test Plan SID 62-109. The data included an outline of the system test program, a system logic diagram, a presentation of system criticality versus hardware requirements, and a revised qualification test schedule with test specimen utilization.

Component vendor selection, including placement of purchase orders, is approximately 95 percent complete. Development testing of breadboard and prototype configurations has been initiated by approximately 80 percent of the 12 selected vendors.

The revised Marquardt reliability program plan has been submitted for formal approval by S&ID and is currently under review.

The following reports were recently published by Marquardt:

"Apollo Reaction Control System; Allocation of Reliability Goals" and "The Demonstration of Conformance of Reliability Requirements for the Gaussian Distribution of Time to Wearout."

The document, "Apollo Program Identification and Traceability Procedure," submitted by Giannini was reviewed and approved. S&ID non-standard parts data sheets have been submitted by Giannini and are presently under review by S&ID to determine their acceptability.

[redacted]

The following Bell Aerospace documents have been reviewed by S&ID and comments have been submitted:

1. BAC Model 8271 design verification test procedure No. 8271-928011 and 8271-928012.

2. BAC Model 8271 acceptance test procedure report No. 8271-928001 and 8271-928002.

The BAC qualification test procedure has been submitted and is presently under review by S&ID.

PLANNED ACTIVITIES

Marquardt is preparing a preliminary report, "Evaluation of Instrumentation System Requirements." Further instrumentation studies will be made to determine the effects of instrumentation error on acceptance or rejection of the finished products, and to describe techniques for determining the values of the standard deviations of instrumentation error and product variability. An analytical study is being conducted to establish a procedure for future correlation of coating thickness and chamber life. The formal design review for the prequalification engine configuration has been delayed because of several injector redesigns. However, the review is scheduled for late October.

Investigation into possible causes of chamber failures will be continued, including ignition characteristics such as oxidizer dribble volume effects, lead and lag of propellant valves, and alternate fuel. Chamber dynamic pressure proof testing inspection or modification of design to minimize ignition delay will be implemented. Investigation of methods for positive indication of SM RC engine disilicide coating quality will continue. Studies will be conducted to improve oxidizer flow passage, to decrease heat soak-back temperatures, and to establish methods for improvement of injector flow distribution. Component design verification and qualification tests are scheduled to commence on approximately 30 percent of the components. Engine qualification tests should begin by the end of the next report period.

[redacted]

SERVICE PROPULSION

SUMMARY

The incidence of the SPS combustion instability appears to have been decreased by use of the AF-29 doublet pattern injector, which has undergone approximately 35 tests of over 1000 seconds of stable accumulated firing time. Continuing problem areas are excessive internal propellant valve leakage and curtailed thrust chamber life at specification performance levels, due to a high rate of specification minimum of 318.7 seconds.

ANALYSIS

An assessment of the service module environment was completed in order to determine the probability of oxidizer leakage and the subsequent formation of sufficient nitric acid in the atmosphere to affect the reliability of the electrical connectors adversely. A meeting was held with electrical design representatives and appropriate recommendations were made, including the use of Titeflex connectors on the engine electrical control harness, and measures to protect the aluminum Deutsch connectors elsewhere in the area. Such measures as anodizing the shell with an acid-resistant coating, minimizing the use of ferrous pins, and assuring a tight seal on the back side of the connectors to prevent slippage of degrading nitric acid vapors into the silicone rubber insert were recommended.

Some improvement in SPS engine gimbal actuator reliability was achieved by design changes, which resulted in more reliable motors and better clutch response time. In order to improve the supplier's ability to reproduce, reliable hardware, an Aerojet quality control representative has been assigned to Lear on a full-time basis. A new contract will be negotiated imposing the reliability requirements of MIL-R-27542 and NCP 200-2.

PROBLEM AREAS

The original regulator design for the SPS was approximately 100 percent overweight. The unit was redesigned to meet specification weight requirements. Subsequently, the subcontractor discovered during

[redacted]

[redacted]

development testing that the outlet pressure (lockup) surged above specification limits within 200 milliseconds on the inlet of the regulator being exposed to a pressure of 3000 psi or greater. This problem is currently being investigated and redesign is indicated. The check valve supplier has indicated that he does not believe he can meet specification leakage requirements under dynamic conditions. This problem is being investigated with respect to allowing an increased pressure drop through the valve in order to increase the spring force on the valve seat.

TEST PROGRAM

The development phase testing has started for all components of the service propulsion system. Development tests on the engine subsystem continue.

The Apollo General Test Plan, SID 62-109, was revised and updated. An economically and technically sound acceptance test plan was devised for items which must undergo destructive testing during the acceptance phase.

Explosion proof-test requirements for the system were outlined and are currently being analyzed for final formulation.

The first simulated altitude firing of a full-scale SPS engine was conducted at AEDC during the last quarter. Aerojet has continued to experience high-frequency instability problems and unstable firings during development testing of the SPS engine. The selection of an injector pattern of the doublet configuration may resolve this problem. However, refinements will be necessary in order to obtain injector and chamber compatibility with respect to chamber erosion.

SUBCONTRACTOR MANAGEMENT

A monthly data review meeting has been established with the subcontractor in which all test results conducted during a given calendar month will be reviewed by the S&ID reliability representative to verify test amplifications and to assure prompt and proper functioning of the failure reporting system, according to the requirements of Table I of MC-999-0025.

S&ID comments on the Aerojet reliability program plan have been accepted by the subcontractor subject to approval by the Apollo Program Manager. A rough draft of the revised plan is to be submitted to S&ID about 30 September 1963.

[redacted]

PLANNED ACTIVITIES

During the next quarter, development testing should be completed on the SPS engine with prequalification scheduled for January 1964. Qualification testing should begin during the next quarter on approximately half of the components of the SPS system.

PROPELLANT MANAGEMENT

SUMMARY

Subcontractor management during this quarter was concerned primarily with identification and traceability, approvals of nonstandard part data sheets, and the requirements and implementation of supplier reliability programs.

Meetings were held with suppliers to discuss the factors which exempt parts from traceability requirements. Identification and traceability procedures received from several suppliers have been reviewed.

Nonstandard part data sheets were received from Simmonds for the parts under consideration for the propellant gaging and mixture ratio control system. Action has been taken on seventeen of the thirty-three items.

SUBCONTRACTOR MANAGEMENT

Subcontractor Coordination

Allison

A coordinating meeting was held to determine the extent of the Allison funded reliability program. As a result of the meeting, the scope of the reliability program is being modified and the new requirements are to be negotiated during the next quarter.

Simmonds Precision Products

A field analysis was conducted to determine the scope of the reliability effort and the manpower requirements for the propellant gaging and mixture ratio control system.

Simmonds has submitted nonstandard part data sheets for approval, and action has been completed or is in process on thirty-three data sheets. S&ID-preferred parts are being incorporated into the design where possible.

[redacted]

J. C. Carter Company

A detailed reliability apportionment study on the RCS and SPS fuel and oxidizer couplings has been completed and submitted for review. Development tests are being conducted on seal designs to evaluate the capabilities of these designs to meet the specification leakage requirement. Results of these tests will be reported when the test program is completed.

Identification and Traceability

The general specification for identification and traceability for subcontractors and suppliers, MA-0201-0209, has been released and is being included in all new and revised procurement specifications. The requirements of this specification and the factors which exempt parts from traceability have been discussed with the following companies during coordination meetings: J. C. Carter, Fairchild Stratos, Giannini, B. H. Hadley, On-Mark, Pelmec, Sargent Fletcher, and United Aircraft Products.

Identification and traceability procedures have been submitted for approval by Fairchild, Giannini, and Pelmec. The Fairchild Stratos procedures have been received and returned for revision. The Giannini procedure has been approved. The Pelmec procedure is currently under review.

PLANNED ACTIVITIES

The investigation into the effect of high-strength material on propellant tank reliability is still in progress. The data analyzed up to now are considerably below the values currently reported by Allison. Revision of the analysis is necessary to consider this factor.

The system interaction which can be detected by present instrumentation is still under study.

[redacted]

[redacted]

III. ELECTRONIC SUBSYSTEM ANALYSIS

SUMMARY

The subcontractor management areas have received more definitive requirements. Reliability plans, qualification testing, and handling plans have been revised to reflect state-of-the-art improvement. Direction and monitoring of supplier high-reliability parts programs are continuing.

Ground rules and instructions have been established with field sites (WSMR and AMR) operations. NASA directed S&ID to prepare Qualification Status Lists for all deliverable flight test articles with an effectivity of boilerplate 6 and beyond. The Qualification Status List, SID 63-784, is based on the lunar mission and a study is in progress to determine the ramifications of this directive on costs and schedules. Early boilerplates (6, 12, and 13) will be certified by mutually agreed flight constraints. S&ID will present NASA with a reoriented Qualification Program Plan to establish the ground rules for meeting the directive of furnishing a status for each vehicle.

During the next quarter, S&ID will devise a plan of action with implementing instructions for the reorganization and appropriate revision of the Apollo General Test Plan to reduce the textual material, and increase the efficiency of updating significant test plan events.

[redacted]

COMMUNICATIONS AND DATA

SUMMARY

The major activities on the communications and data (C&D) subsystem have been concerned with proper implementation of the subcontractor's reliability effort to comply with the identification and traceability, soldering, and high-reliability parts procurement requirements of Apollo. Coordination activities with the subcontractor have continued in support of these efforts. Design information is now available to allow circuit stress and parameter variation analyses as well as more refined configuration and trade-off studies to assure attainment of the C&D subsystem reliability objectives.

ANALYSIS

VHF/FM Transmitter

A reliability study of the Conic Corporation telemetry transmitter (CTM-225) was conducted for comparison with the Collins Radio Company (CRC) VHF/FM transmitter. The Conic transmitter is not constructed exclusively of high-reliability parts; its predicted reliability is 0.998831 for 10 operating hours. With high reliability components the predicted reliability of this unit is 0.999855, comparing favorably with the 0.999825 reliability of the Collins Radio Company transmitter with equivalent parts. Because of weight savings with the Conic set, two complete spares are possible within the same weight constraint. This would result in a reliability of 0.999999 for the existing Conic configuration. Therefore, it was recommended that the Conic design be utilized with a maximum of high reliability parts with redundancy if necessary.

Signal-Conditioning Equipment

Because of the multi-function configuration of the signal-conditioning equipment, the numerical reliability requirements were converted to apply to each specific function. Table 3-1 lists each function with its apportioned reliability.

Audio Center Equipment

A worst-case computer stress analysis was performed on the audio center equipment for dc operation. All parts operated conservatively except under maximum temperature conditions. With maximum cold-plate

Table 3-1. Signal Conditioning Equipment Apportioned Reliability

Function	Apportioned Reliability	Number Required per System
Phase sensitive demodulation	0.99864	1
Frequency sensitive demodulation	0.99853	1
DC amplification	0.99858	15
DC attenuation	0.99894	4
AC to DC conversion	0.99861	4
+10 volt DC power	0.99954	1
+5 volt DC power	0.99954	1

temperature, dissipation in the four output stage transistors of the headset amplifier and the microphone amplifier was found to approach the maximum recommended for the C&D subsystem. The worst-case collector dissipation was calculated to be 194.7 mw compared to a recommended maximum of 205 mw.

An analysis of the effect of maximum audio signals upon transistor dissipation is being performed to augment the dc analysis. Because the maximum recommended ratings include adequate derating, a design change may not be indicated. However, further investigation, based upon part life test data will be conducted to determine the effect of existent stress levels on transistor failure rate.

S-Band Equipment

An evaluation was performed to facilitate a reliability-weight trade-off study based upon three configurations of the unified S-band equipment and S-band power amplifier. The configurations considered were the following:

1. Redundant unified S-band transponders and S-band power amplifiers located in the service module with relay switching to allow placement of either of the redundant devices into operation

2. Redundant unified S-band transponders and one diplexer located in the command module; one diplexer and redundant power amplifiers located in the service module

3. Redundant unified S-band transponders and power amplifiers located in the command module (manually replaceable)

The reliability numerics obtained for these three configurations are as follows:

Configuration	Reliability Prediction
1	0.999101
2	0.999511
3	0.999722

Configuration 1, with a reliability of 0.999101, offers the greatest savings in command module weight but does not permit employment of the S-band equipment once the service module has separated. Configuration 2, with a reliability of 0.999511, allows some weight savings and does permit use of the S-band equipment during the entry phase, since the transponder is located in the command module. Configuration 3 yields the highest reliability, 0.999722. It is a variation of the present configuration, which includes only one S-band power amplifier.

Of the three configurations the third was recommended, but comment was withheld on whether to have a single or redundant S-band power amplifiers. Comment will be forthcoming based upon a spares optimization study on the system level.

An analysis was also conducted to compare manual replacement of failed equipment with remote switching, using the present configuration. The reliability numeric resulting from manual replacement was estimated to be 0.998452 as against 0.998435 with switching. Although the reliability achieved by manual replacement exceeds that for switching, equipment operation would be interrupted by the former method for fifteen to forty-five minutes during replacement. Therefore, it was recommended that the decision on which configuration to employ be based primarily on the time criticality of the function.

[redacted]

TEST PROGRAM

To assist in obtaining high reliability parts, S&ID source control drawings were transmitted to the Collins Radio Co., mainly during the month of July, 1963.

A deviation was granted to the Collins Radio Co. concerning the acceptance vibration of deliverable hardware. A sinusoidal vibration was allowed in lieu of random vibration acceptance testing.

S&ID presented to NASA MSC in Houston, Texas, on 21 June 1963 the complete scope of the test effort for the communications and data subsystem. The presentation included the subcontractor effort from the qualification of parts and materials through the qualification of components to the acceptance testing of deliverable hardware. Also included was S&ID's in-house activity from acceptance through installation and shipping of the complete spacecraft.

S&ID personnel participated in a field analysis for the digital up-data link cost proposal during the period of 5 to 9 August 1963. Major discrepancies became apparent and were discussed in detail with the subcontractor.

A meeting was held on 11 September 1963 with Collins Radio Co. representatives to determine the format and presentation of their acceptance test procedures and data sheet.

The VHF/2KMC R & D antenna and radome completed qualification testing at Wyle Laboratory on 31 July 1963. CRC reported that the X rays taken on one of the qualification units revealed a slight parting of the honeycomb from the aluminum skin. This problem is now being investigated by S&ID.

The qualification test program on the low-pass VHF filter began on 16 August at Wyle Laboratory. The tentative test schedule is as follows:

Test	Facility
Humidity	Wyle Laboratory
High temperature	Ranter
Low temperature	Ranter
Altitude	Ranter
Vibration	Wyle Laboratory
Acoustics	Nor-Air

Collins Radio Co., their subcontractors, and their part suppliers are in the process of qualifying parts for the C&D subsystem.

There have been failures of the traveling wave tube (TWT) supplied to Collins Radio by Hughes Aircraft. As a result, an alternate source (Litton Industries) has been selected for a parallel development of a klystron that will replace the TWT.

SUBCONTRACTOR MANAGEMENT

A meeting between members of S&ID and Collins Radio Co. was held on 30 and 31 July 1963 to discuss the reliability effort on the C&D subsystem. The following subjects were discussed.

Identification and Traceability (I&T)

CRC was informed that MA-0201-0209 would replace MQ-0503-002 as the governing I&T specification on approximately 14 August 1963. S&ID supplied clarification of specific paragraphs of MA-0201-0209 and MQ-0503-002. MA-0201-0209 requires that one new Type I document, the I&T Program Plan, be supplied by CRC within thirty days after MA-0201-0209 becomes a part of the procurement package. Requests for approval of the exemption of parts from I&T requirements will be submitted according to the following schedule.

Equipment	Electronic Parts	Mechanical Parts
HF transceiver	15 July 1963	15 August 1963
VHF recovery beacon	7 October 1963	7 October 1963
VHF/FM transmitter	15 September 1963	1 September 1963
VHF/AM transmitter receiver	1 September 1963	1 September 1963
Unified S-band equipment	15 December 1963	15 December 1963
C-band transponder	1 November 1963	1 November 1963

[redacted]

Equipment	Electronic Parts	Mechanical Parts
S-band power amplifier	1 September 1963	1 September 1963
Signal conditioner	1 January 1964	1 January 1964
PCM telemetry equipment	7 November 1963	7 November 1963
Audio center	1 November 1963	1 October 1963
Data storage	1 August 1963	1 September 1963
Premodulation processor	7 October 1963	7 October 1963

Logic Diagrams

S&ID transmitted to CRC a set of reliability logic diagrams of the C&D subsystem constructed on the sparable subassembly level. The advantages of CRC generating these logic diagrams, such as CRC access to packaging change information, were discussed. CRC stated that work had started in this area and that initial results would be forwarded to S&ID.

Spares

The sparing concept for the C&D subsystem was discussed with the following spares designated by S&ID for the LOR mission:

1. Unified S-band equipment
2. Up-voice discriminator, premodulation processor

Computer Circuit Analyses

The status of computer circuit analyses of CRC was considered. CRC presented the results from an ac analysis of the audio center amplifier in which the stage-by-stage design requirements were shown to be met. However, the results did not reflect the worst-case condition. Nominal inputs were assumed for each stage. S&ID questioned the value of this type of analysis and suggested that the following procedure be utilized:

1. Analysis of performance. A one-at-a-time parameter variation analyis should be carried out first. This should be followed by a worst-case analysis if the results of the initial analysis indicate that performance requirements would not be met under the worst-case condition. Results of the analyses would suggest

[redacted]

the necessary corrective action. Compromising effects of the required corrective action on other parameters of the package would have to be evaluated with the understanding that it is desirable, but not mandatory, that the worst-case condition be satisfied.

2. Analysis of electrical stress. Part application test data supplemented by analyses should be reviewed. In instances where maximum recommended stress levels may be exceeded a worst-case analysis should be performed. Corrective action should follow the same guidelines given for performance analyses.

CRC circuit analyses are presently being performed in the following order:

1. AC one-at-a-time parameter variation analysis
2. DC one-at-a-time parameter variation analysis
3. Monte Carlo circuit synthesis
4. Worst-case analysis

Prior to implementation of the S&ID suggestions the matter will be discussed with relevant design personnel at CRC.

S&ID informed CRC that a Mandex worst-case dc analysis had been performed on the audio center equipment, and that four parts were found to operate at marginal stress levels.

Parts Procurement From Distributors

S&ID inquired whether the purchasing of Allen-Bradley resistors from Newark Electronics (a parts distributor) for E Models would be continued for flight hardware. CRC indicated that this practice would be continued for D-Model equipment because delivery cycles available from Newark corresponded to CRC schedules. S&ID stated that this practice was not in conformance with the Apollo high-reliability program and that a directive was forthcoming which would not allow the utilization in D-Model equipment of parts procured from distributors. S&ID outlined the more prominent disadvantages of this practice as follows:

1. Uncontrolled source of manufacture
2. Uncontrolled handling and storage

[redacted]

3. Inability to enforce identification and traceability requirements

4. Inability to meet equipment reliability requirements or to make realistic reliability assessments

A communication was sent to CRC, dated 31 July 1963, stating that it would be permissible to purchase Allen-Bradley resistors for E-Model equipment from a retail outlet if assurance could be offered that the electrical parameters and physical configuration are the same as those of the high-reliability counterpart to be used in the D and P equipments but that no parts, similarly purchased, are to be used in D and P equipments.

Equipment Reliability Status

The revised equipment reliability estimates are listed in Table 3-2. CRC indicated that part failure rates reflecting existent electrical and thermal stresses, and based upon part application tests, will be available approximately 1 October 1963.

Table 3-2. C&D Subsystem Revised Reliability Predictions

Equipment	Reliability	
	Prediction	Apportionment
VHF recovery beacon	0.99902	0.99981
Audio center	0.99596	0.9969
VHF/AM transmitter-receiver	0.99914	0.9990
VHF/FM transmitter	0.99983	0.99996
Premodulation processor	0.9741	0.9967
Unified S-band equipment	0.9905	0.9954
Data storage	0.9925	0.9930
Signal conditioner	0.9741	0.9880
C-band transponder	0.9991	0.9995
PCM telemetry	0.9632	0.9630
HF transceiver	0.9990	0.99972
S-band power amplifier	0.9933	0.9969

Traveling Wave Tube Status

According to CRC, there have been six failures of the traveling wave tube since the development program began. These failures were due primarily to handling damage or incompatible test apparatus. The most recent failure was caused by voltage breakdown in the teflon sleeve located between the collector and output coupler. Corrective action consisted of thickening the sleeve and changing the configuration to two concentric layers. This change will be initiated on serial number 40. The TWT manufacturer has indicated that it has data on this device to substantiate a failure rate of 2 percent per 1000 hours at 80 percent confidence level. This data has been requested by CRC. To further assure reliable S-band transmission the back-up klystron program is now in progress.

Part Specifications

The omission by CRC of failure rate and failure rate verification data from part procurement specifications was discussed. The position of S&ID has been that documentation of this data on the part specifications is mandatory in order to establish realistic reliability assessments. It was agreed that a failure rate objective would be included in each part procurement specification.

Part Improvement and Part Approval Test Status

S&ID requested the part improvement and part approval test status from CRC. CRC submitted documentation of the test status by CRC part number and requested that General Electric be included on the approved source list for the 2N918 Transistor.

Failure Effects Analysis

In compliance with a request by S&ID, CRC transmitted the following schedule for equipment failure effects analyses to be conducted on the part level.

Equipment	Date
VHF/ AM transmitter-receiver	3 July 1963
VHF/ FM transmitter	11 July 1963
Audio center	17 July 1963
Premodulation processor	24 July 1963
HF transceiver	9 August 1963
S-band power amplifier	August 1963
VHF recovery beacon	August 1963
Signal conditioner	August 1963
Multiplexer	September 1963
PCM telemetry	15 September 1963
Data storage	15 September 1963
Unified S-band equipment	15 September 1963
C-band transponder	15 September 1963

A meeting between S&ID and CRC was held on 13 and 14 June 1963 to consider the design and development of the signal conditioning equipment. The power supply, frequency demodulator, and phase demodulator were found to have been breadboarded and electrically checked. Sources had been selected and design initiated for the ac to dc converter, the dc amplifier, and the attenuator. The power supply design included two series diodes in each leg of the bridge rectifiers, affording operational redundancy for the most frequent diode failure mode. On S&ID inquiry, CRC indicated that the selection of fixed resistors in lieu of the variable resistors now employed is not feasible as a means of improving reliability. S&ID requested that CRC determine the effect on reliability, weight, volume, and cost of using microminiaturization, where feasible, in the signal-conditioning equipment and the PCM telemetry equipment.

On 2 July 1963 a list of requests for deviation from MSFC-PROC-158 was received from CRC on behalf of Radiation, Inc. The requests and the subsequent rejoinders by S&ID are summarized as follows:

1. It was requested that, in deviation from Paragraph VI.B.5.d, clinching of leads be eliminated and that lead protrusion through the circuit board be reduced from 0.0625 inches to 0.020 inches in order to improve reliability and avoid the loss of a module from the SEP. This procedure was considered acceptable if Paragraph VI.B.5.e was observed.

2. It was requested that, in deviation from Paragraph VI.B.5.g, component leads connecting two-sided circuitry be soldered on only one side because the assembly design renders it impossible to solder both sides. After evaluation of the assembly design, this change was considered acceptable.

3. It was queried whether soldering of plated-through holes is sufficient to meet the requirements of Paragraph VI.B.5.h (2) in regard to their use as an electrical connection. Since solder fill is considered an adequate aid to the plated hole, this interpretation was accepted.

The requests for deviation from NCP 200-2 received to date from CRC are listed below with the position taken by S&ID.

1. Paragraph 4.4

   CRC: All electrical and mechanical parts on E Models will be considered exempt because of cost and schedule factors. Equipment will be traceable and serialized from the lowest functional subassembly level. Material utilized in models built in the CRC Engineering division, such as solder, bonding agents, paint, and wire are not adequately identified to permit traceability from point of usage back to supplier. Material used in construction of pilot line models will be so identified. NAA: E-Model equipment will be traceable and serialized from the module level forward. Unless a part is considered to be at the module level, it will be exempt. Therefore, the deviation is acceptable.

2. Paragraph 5.2

   CRC: Because of schedule requirements, E-Model parts must be procured, in some cases, prior to completion of facilities

[redacted]

surveys. Wherever possible, E-Model parts will be procured from the same manufacturers planned for D-Model parts. Supplier evaluation will be completed prior to D-Model part procurement.
NAA: As a minimum requirement E-Model parts must have the same electrical parameters and general physical configuration as those of the high reliability counterpart to be used in the D-Model equipment. In order to facilitate this, E-Model parts should be procured from the same manufacturers planned for D-Model parts. It is not necessary to complete the supplier evaluation prior to E-Model parts procurement, but CRC must not allow this practice to compromise the procurement schedule for D-Model parts.

3. Paragraph 5.3.1 (D) (2) Supplier Quality Assurance Program

   CRC: Common usage items, such as nuts, bolts, sheet metal, terminals, and adhesives, are not procured on a project basis for E Models. Standard commercial or MIL parts are procured, stocked, and issued to specific projects as required. Special requirements cannot be imposed on these common usage parts. Exemption does not apply to materials procured specifically under the Apollo contract.
   NAA: Assuming that "special requirements" signifies I&T requirements, this topic is covered under the comments on Paragraph 4.4; if not, "special requirements" must be clarified.

4. Paragraph 5.3.1 (D) (2), Supplier Quality Assurance Program

   CRC: Allen Bradley (qualified resistors) will accept no special requirements (E Model parts only).
   NAA: Assuming that "special requirements" signifies I&T requirements, this topic is covered under the comments on Paragraph 4.4; if not, "special requirements" must be clarified.

5. Paragraph 7.4. (Each operation of fabrication and inspection traceable to the individual responsible.)

   CRC: Records permitting traceability to the individual will be maintained on E Models through a traceability system which will not be fully implemented until the start of D-Model building.
   NAA: The means of tracing on the module level for E-Model equipment should allow for tracing to the individual responsible for assembly of each module. Therefore, this information should be available for each module.

6. Paragraph 8.1 Material Review

   CRC: Formal MRB action during construction of the first engineering E Models places unnecessary constraints on the design engineer and delays the build of this equipment. CRC permits the use of material containing minor or incidental nonconformances at the engineer's discretion, provided that the ultimate use of these parts is documented.
   NAA: This practice is acceptable for those nonconformances that in no way curtail the ability of the equipment to perform correctly under the electrical, thermal, and environmental stresses that it is expected to undergo, provided that adequate documentation is maintained to allow surveillance and reevaluation.

7. Paragraph 13.2 Certification of Solders

   CRC: Soldering of electrical connections within E-1 and E-2 will be performed by laboratory technicians to commercial standards. CRC believes the application of MSFC-PROC-158 to these units is unwarranted, since these models will be used only for in-house testing to determine necessary changes or improvements.
   NAA: This practice is acceptable.

8. Paragraph 7.5.2 Material Control

   CRC: Special-products operating procedure NBR 7 (traceability) is complete and will be in full operation for E-Model units. However, the data collection center is not set up to handle traceability information in the unrevised format. Thus, complete traceability as such will not be in effect on E-Model units.
   NAA: Traceability must be maintained on E-Model equipment from the module level forward. Complete traçeability (to the part level) will not be necessary for E-Model equipment.

PLANNED ACTIVITIES

The Collins parts qualification program will continue during the next quarter.

In the next quarter a more intensive effort to assure that inherent design reliability will be achieved will be possible due to the advent of detailed design information and preliminary test data. This will be

[redacted]

accomplished by review of parts selection and part stress data, performance of parameter variation analyses and configuration trade-off studies. The failure effects analysis (FEA) on the part level will be received from the subcontractor and integrated into the overall Apollo System FEA. A more refined estimate of the contribution of the C & D Subsystem to crew safety will be made and the subcontractor's reliability program plan will receive final review. The subcontractor's identification and traceability (I & T) program plan and I & T exemption lists will be reviewed. Coordination activities with the subcontractor will continue.

GUIDANCE AND NAVIGATION

SUMMARY

The subassembly logic diagrams were revised to conform with present information received from Massachusetts Institute of Technology. Analyses have been performed to update the logic configuration of the temperature controller. Reliability values for operating G&N equipment have been calculated for three critical lunar orbit mission phases. A preliminary evaluation of MIT reliability logic networks has revealed that further analysis is necessary before the information can be utilized by S&ID.

ANALYSIS

MIT Logic Information

A preliminary analysis was performed on MIT reliability logic networks, as submitted to S&ID by MIT through NASA/RASPO/MIT. This MIT logic information was furnished to the replaceable module level for those operational modes in which the subassembly logic is a simple series arrangement. This information cannot be utilized in its present form by S&ID in support of the logic network studies. The action item of MIT/S&ID coordination meeting No. 58 reads:

> MIT will furnish S&ID with reliability logic diagrams to the replaceable module level for those equipments in which the subassembly logic is not a simple series arrangement.

The preliminary analysis of MIT's response to the action item has revealed that the document, in its present form, does not satisfy the intent of the action item and appears confusing and inconsistent with other MIT-supplied information. For instance, the 14-day maximum mission power profile recently received from MIT reveals that the AGC will be consuming full power for the full 336 hours. The response to the action item states that only eight modules need be operational for the computer ΔV, IMU memory, and it is assumed that there are coast modes during which the AGC has no computations to perform. Further analysis of the document will determine the extent of clarification needed.

[redacted]

Subassembly Logic Diagrams

Recent revisions of subassembly logic for the G&N equipment have been completed and are compatible with MIT's handout information distributed during MIT/S&ID coordination meeting No. 68B. The latest logic diagrams at the replaceable module level are noted in Figure 3-2 at the end of this section. Nonreplaceable modules are denoted by a double line, and modules which must be spared together by a dotted line enclosure. These diagrams are being used in the electronic integrated system study of AFRM 011 and 018 to facilitate optimization of in-flight spares allocations for maximum spacecraft reliability with minimum weight.

A temperature control system logic study was performed to define more accurately the functions and backup capabilities of the system. The new configuration is shown in Figure 3-1. The temperature control logic configuration was derived from the Apollo IMU Temperature Control System Schematic, NASA Drawing 1010039. From this drawing failure rates for the modules were determined by parts count estimates.

Critical Mission Phase Reliability Analysis

An analysis was performed to determine the reliability of the series-arranged G&N equipment operating during three critical mission phases: translunar injection, lunar orbit injection, and transearth injection. Table 3-3, as taken from MIT document, Apollo Guidance and Navigation System Reliability Apportionments and Initial Analysis, was used to calculate the failure rates and reliability of the critical mission phases. These values are found in Table 3-4 and Table 3-5.

Reliability calculations for the three mission phases noted above were completed for both the maximum 14-day mission and the 8-day nominal mission. Notice should be given to the reliability values of the computer (AGC) with and without spares in Tables 3-4 and 3-5, respectively. Verification of modules spared to achieve such high reliability in the AGC is not possible at present because weight information has not been available.

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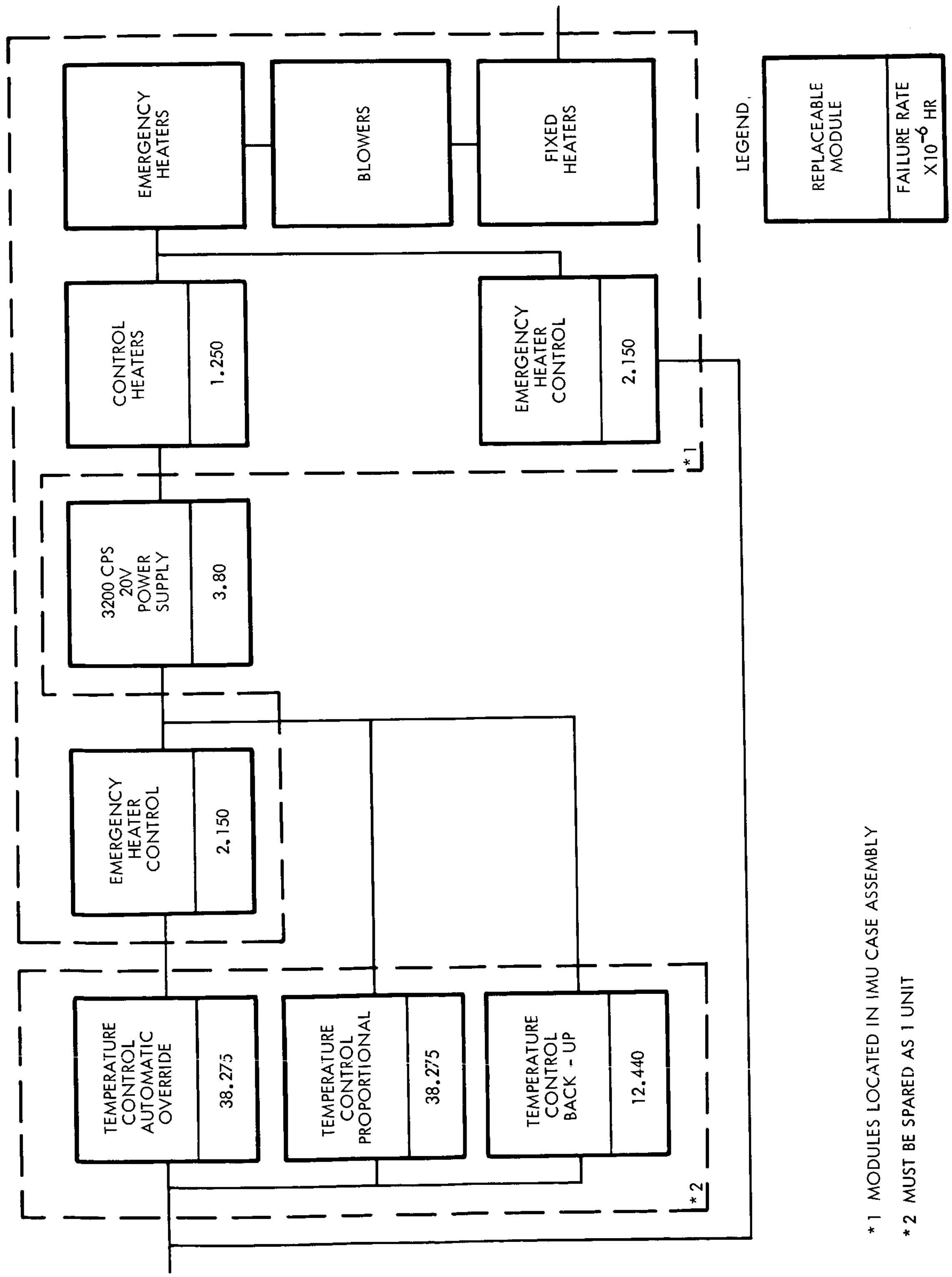

*1 MODULES LOCATED IN IMU CASE ASSEMBLY

*2 MUST BE SPARED AS 1 UNIT

Figure 3-1. Temperature Control System

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Table 3-3. MIT G&N Predicted Mission Success Reliability Values

Subsystem	Operating Time (hrs)			Predicted Reliability*	
	Full Power	Standby	Off	Without Spares	With Spares
Coupling display unit	22	-	135	0.99652	0.999994
Sextant and telescope optics	22	-	135	0.99787	0.997870
Apollo guidance computer	45	112	-	0.89826	0.999970
Inertial measurement unit	22	-	135	0.99626	0.996260
Inertial measurement electronics	22	135	-	0.99320	0.999988
Sextant and telescope optics electronics	22	-	135	0.99635	0.999990
Final approach equipment	2	-	155	0.99992	0.999920
G&N Mission Success Probability				0.88054	0.994000

*Present State-of-the-Art Values

ASSOCIATE CONTRACTOR COORDINATION

As a result of an action item generated at MIT/S&ID coordination meeting No. 68B, MIT has submitted a reply entitled "Power Profile for G&N Loads." Contents reveal the G&N system profile of the average power consumption based upon a particular 14-day mission.

In response to a coordination meeting No. 58 action item, MIT has submitted the document, Reliability Logic Networks. The adequacy of this document is undetermined at present because of the format employed by MIT for presentation. Correlation and transformation of MIT reliability logic network information to S&ID's format is presently underway and will be used to determir the adequacy of this document.

[redacted] [redacted]

Table 3-4. G&N Critical Mission Phase Apportioned Reliability With Spares

Phases	Maximum Mission (hr)	Nominal Mission (hr)	G&N Equipment Operating	Failure Rates (λ/hr)	λt_{max}	λt_{nom}	Reliability	
							Maximum	Nominal
Translunar injection	0.10	0.08	Inertial Measurement Unit (IMU)	170.0764×10^{-6}	17.0070×10^{-6}	13.605×10^{-6}	0.99998299	0.99998639
			Coupling Display Unit - IMU (CDUM)	0.1630×10^{-6}	0.0163×10^{-6}	0.013×10^{-6}	0.99999998	0.99999998
			Apollo Guidance Computer (AGC)	0.1910×10^{-6}	0.0191×10^{-6}	0.015×10^{-6}	0.99999998	0.99999998
			Total	170.430×10^{-6}	17.0400×10^{-6}	13.630×10^{-6}	0.99998296	0.99998637
Lunar orbit injection	0.10	0.09	IMU	170.0764×10^{-6}	17.0070×10^{-6}	15.306×10^{-6}	0.99998299	0.99998468
			CDUM	0.1630×10^{-6}	0.0160×10^{-6}	0.014×10^{-6}	0.99999998	0.99999998
			AGC	0.1910×10^{-6}	0.0191×10^{-6}	0.017×10^{-6}	0.99999998	0.99999998
			Total	170.430×10^{-6}	17.0400×10^{-6}	15.338×10^{-6}	0.99998296	0.99998466
Transearth injection	0.05	0.04	IMU	170.0760×10^{-6}	8.5040×10^{-6}	6.803×10^{-6}	0.99999149	0.99999319
			CDUM	0.1630×10^{-6}	0.0080×10^{-6}	0.006×10^{-6}	0.99999999	0.99999999
			AGC	0.1910×10^{-6}	0.0090×10^{-6}	0.008×10^{-6}	0.99999999	0.99999999
			Total	170.430×10^{-6}	8.5200×10^{-6}	6.817×10^{-6}	0.99999148	0.99999318

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Table 3-5. G&N Critical Mission Phase Predicted Reliability Without Spares

Phases	Maximum Mission (hr)	Nominal Mission (hr)	G&N Equipment Operating	Failure Rates (λ/hr)	λt_{max}	λt_{nom}	Reliability Maximum	Reliability Nominal
Translunar injection	0.10	0.08	Inertial Measurement Unit (IMU)	213.30×10^{-6}	21.330×10^{-6}	17.060×10^{-6}	0.9999787	0.9999829
			Coupling Display Unit - IMU (CDUM)	94.52×10^{-6}	9.452×10^{-6}	7.560×10^{-6}	0.9999905	0.9999924
			Apollo Guidance Computer (AGC)	683.40×10^{-6}	68.340×10^{-6}	54.670×10^{-6}	0.9999316	0.9999453
			Total	991.22×10^{-6}	99.122×10^{-6}	79.290×10^{-6}	0.9999008	0.9999207
Lunar orbit injection	0.10	0.09	IMU	213.30×10^{-6}	21.330×10^{-6}	19.207×10^{-6}	0.9999787	0.9999808
			CDUM	94.52×10^{-6}	9.452×10^{-6}	8.506×10^{-6}	0.9999905	0.9999915
			AGC	683.40×10^{-6}	68.340×10^{-6}	61.506×10^{-6}	0.9999317	0.9999385
			Total	991.22×10^{-6}	99.122×10^{-6}	89.219×10^{-6}	0.9999009	0.9999108
Transearth injection	0.05	0.04	IMU	213.30×10^{-6}	10.665×10^{-6}	8.532×10^{-6}	0.9999893	0.9999915
			CDUM	94.52×10^{-6}	4.726×10^{-6}	3.781×10^{-6}	0.9999953	0.9999962
			AGC	683.40×10^{-6}	34.170×10^{-6}	27.336×10^{-6}	0.9999659	0.9999727
			Total	991.22×10^{-6}	49.561×10^{-6}	39.649×10^{-6}	0.9999504	0.9999603

[redacted]

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S&ID has transmitted to MIT the Approved Parts List and High-Reliability Component Specifications released by S&ID to date.

S&ID Reliability has received a preliminary copy of MIT's computer tab run on the Failure Effects Analysis at the subassembly level. A coordination meeting will be arranged to discuss this data with MIT after it has been reviewed by S&ID.

The following documents have been received from MIT during this quarter.

1. General Design Characteristics of the Apollo Computer (R-410)

2. Slide Reprints of Presentation at NASA Headquarters, Washington, D.C. (E-1346)

3. Radar Requirements for Primary Guidance and Navigation Operation (R-404)

4. Minutes of MIT/GAEC Meeting, dated 7 August 1963

5. Monthly Technical Progress Report, Project Apollo Guidance and Navigation Program; March and April 1963 (E-1307, E-1308)

6. Qualification Status List (capacitors, connectors, diodes, relays and switches, resistors, rotating components, transformers and inductors, transistors, and miscellaneous).

The following documents have been received from Grumman Aircraft (GAEC) during this quarter.

1. The Design Control Specification for the Navigation and Guidance Subsystem Rendezvous, Radar/Transponder and Landing Radar Sections

2. Backup Guidance Requirements

3. Mission Plan

4. Radar Implementation Study

PLANNED ACTIVITIES

Further analyses will be necessary to convert the MIT-furnished reliability logic networks into a format usable in S&ID reliability studies. The operational mode subassembly logic information furnished by MIT will

[redacted]

have to be converted into equipment subassembly logic diagrams for use in mission success and crew safety reliability studies. The analysis will also determine whether further clarification by MIT is necessary. Steps will then be taken to obtain any necessary clarification. As a result of this analysis, another revision of the G&N subassembly logic diagrams may be indicated.

MIT is expected to furnish S&ID with current information on the AGC. This information will be used to update and revise the AGC subassembly logic diagrams, as well as to update the Electronic Systems Spares List.

A preliminary copy of MIT's computer tab run subassembly Failure Effects Analysis (FEA) has been received by S&ID Reliability. A meeting has been set up to discuss the FEA at the subassembly level, and clarify any questions S&ID might have. The FEA will then be used, along with other pertinent information, to update the subassembly logic diagrams, as well as S&ID Reliability's subassembly Failure Effects Analysis.

S&ID is beginning to receive coordination documentation from GAEC. A reliability coordination meeting between S&ID and GAEC will be scheduled during the upcoming quarter. During the next quarter the documents received will be reviewed and their contents evaluated. Evaluations will be made as to the G&N backup requirements, CM backup capabilities for LEM recovery, and GAEC reliability calculations.

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APOLLO GUIDANCE COMPUTER

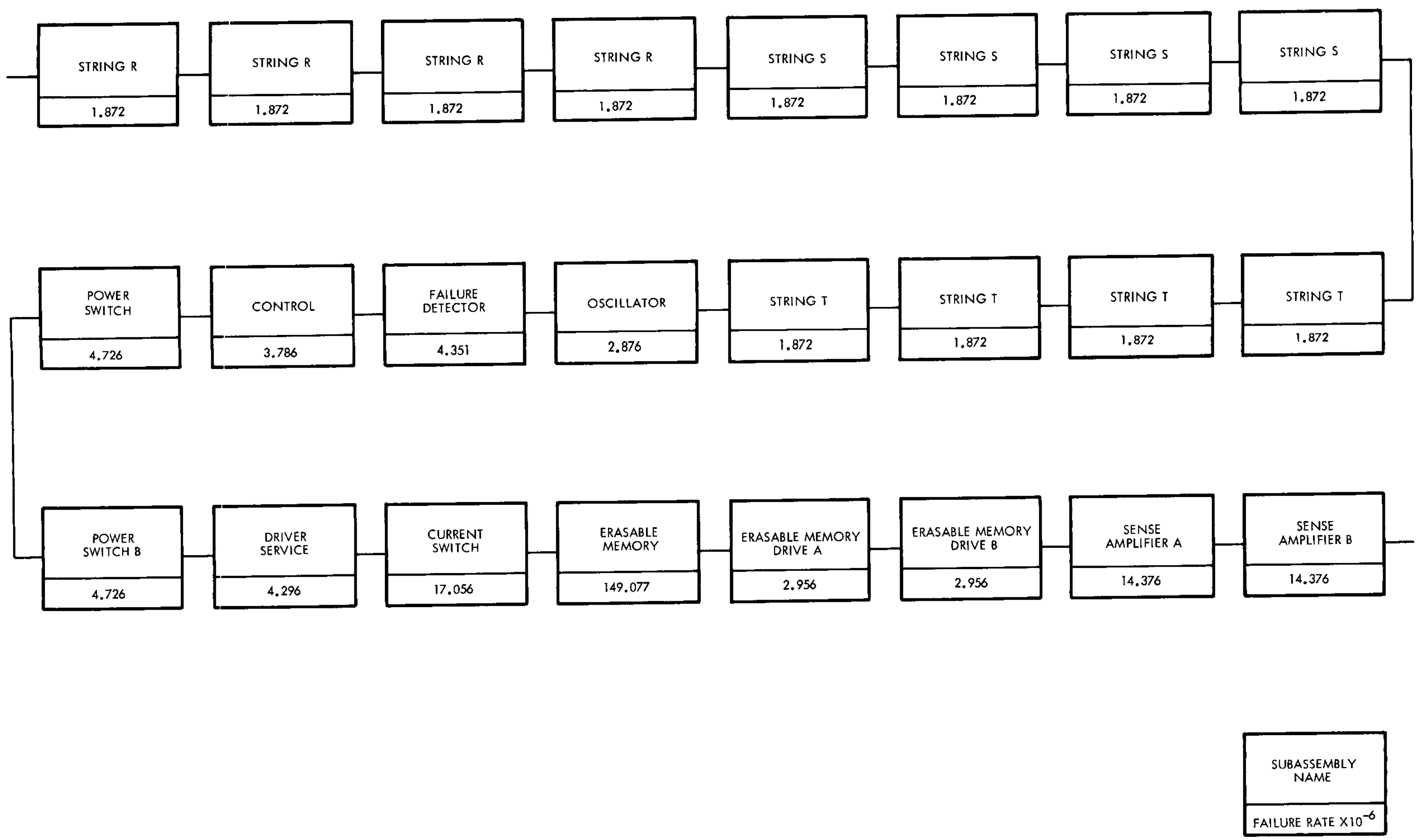

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 1 of 13)

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APOLLO GUIDANCE COMPUTER

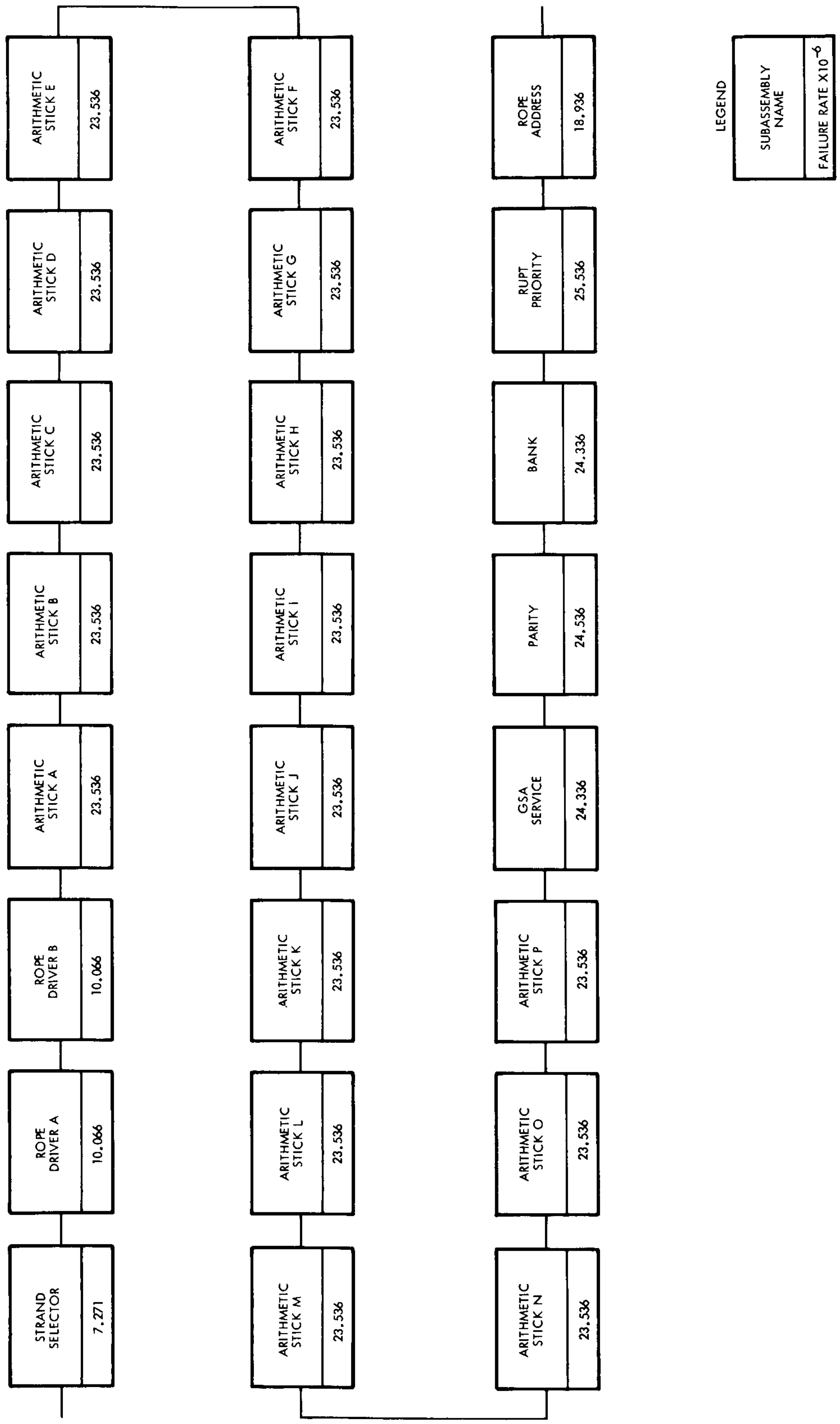

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 2 of 13)

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APOLLO GUIDANCE COMPUTER

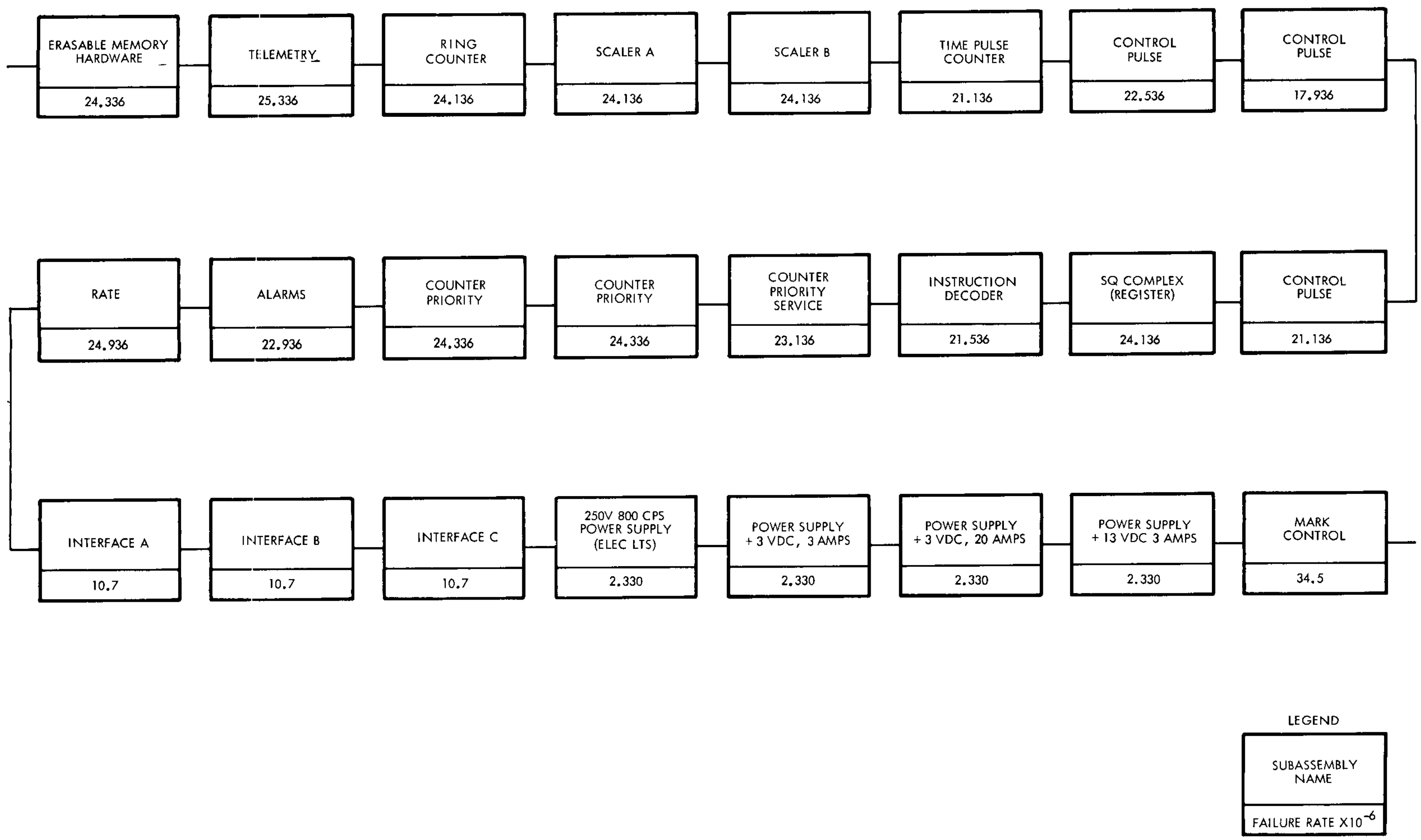

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer

(Sheet 3 of 13)

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INERTIAL MEASUREMENT UNIT

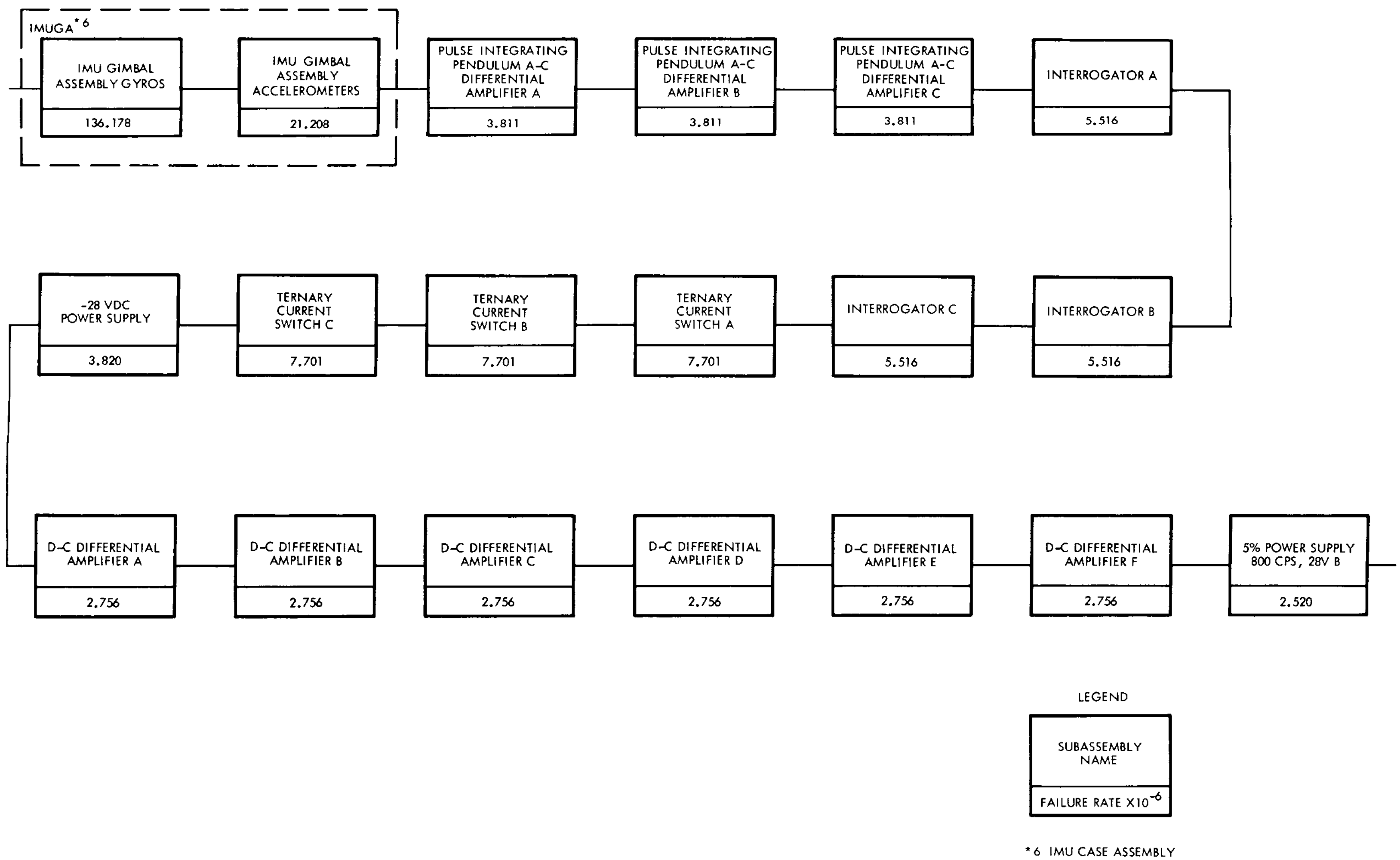

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer

(Sheet 4 of 13)

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INERTIAL MEASUREMENT UNIT

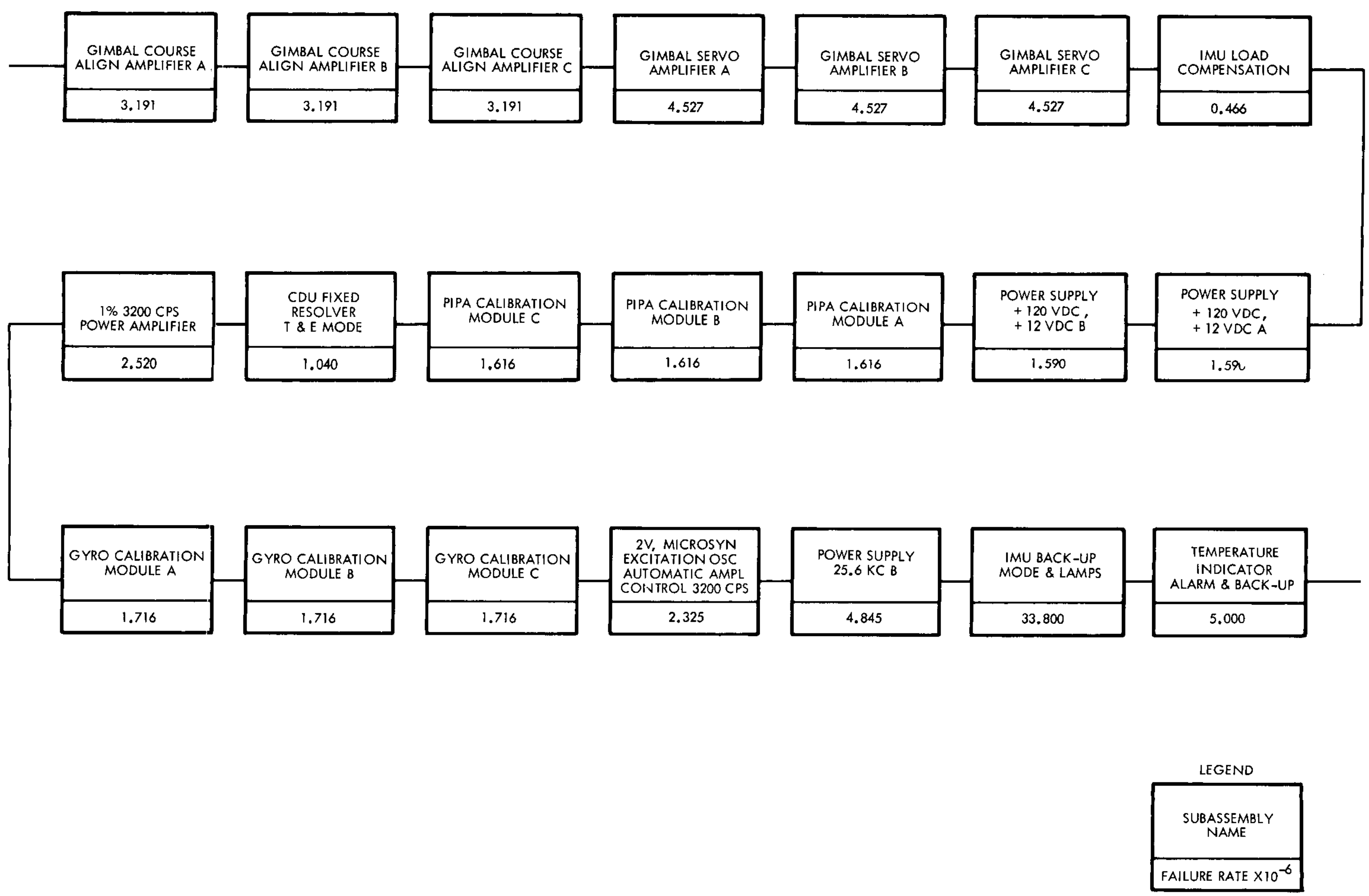

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 5 of 13)

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INERTIAL MEASUREMENT UNIT

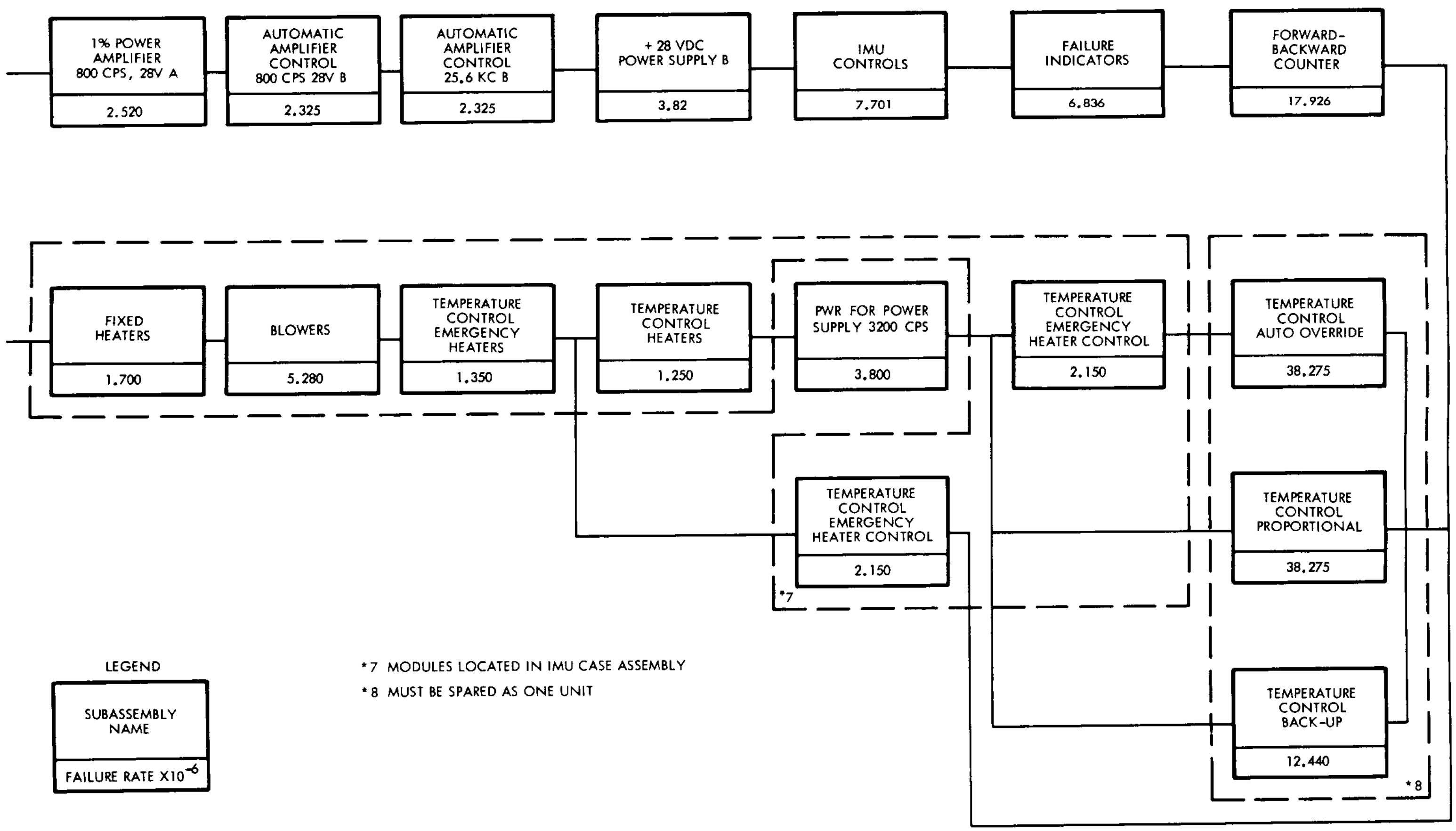

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 6 of 13)

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COUPLING DISPLAY - INERTIAL MEASUREMENT UNIT

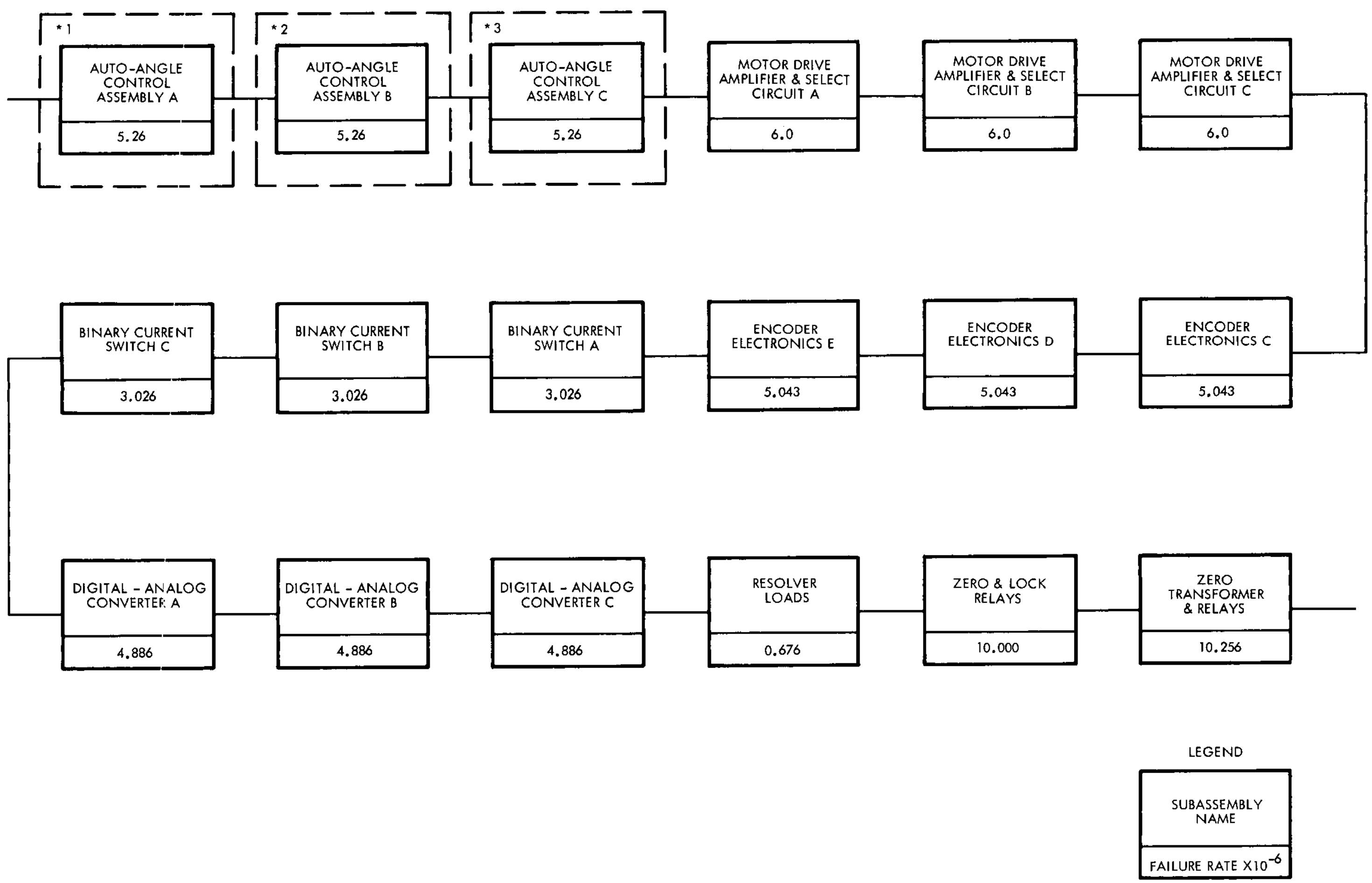
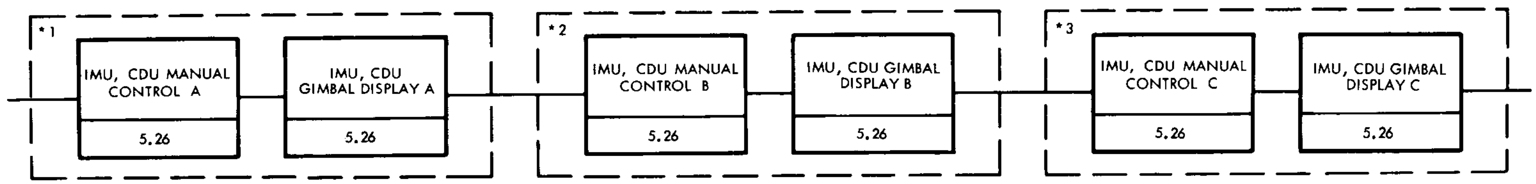


Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer
(Sheet 7 of 13)

COUPLING DISPLAY UNIT - INERTIAL MEASUREMENT UNIT. MANUAL CONTROLS AND DISPLAYS



*1 MUST BE SPARED WITH IMU, CDU A

*2 MUST BE SPARED WITH IMU, CDU B

*3 MUST BE SPARED WITH IMU, CDU C

COUPLING DISPLAY UNIT - OPTICS

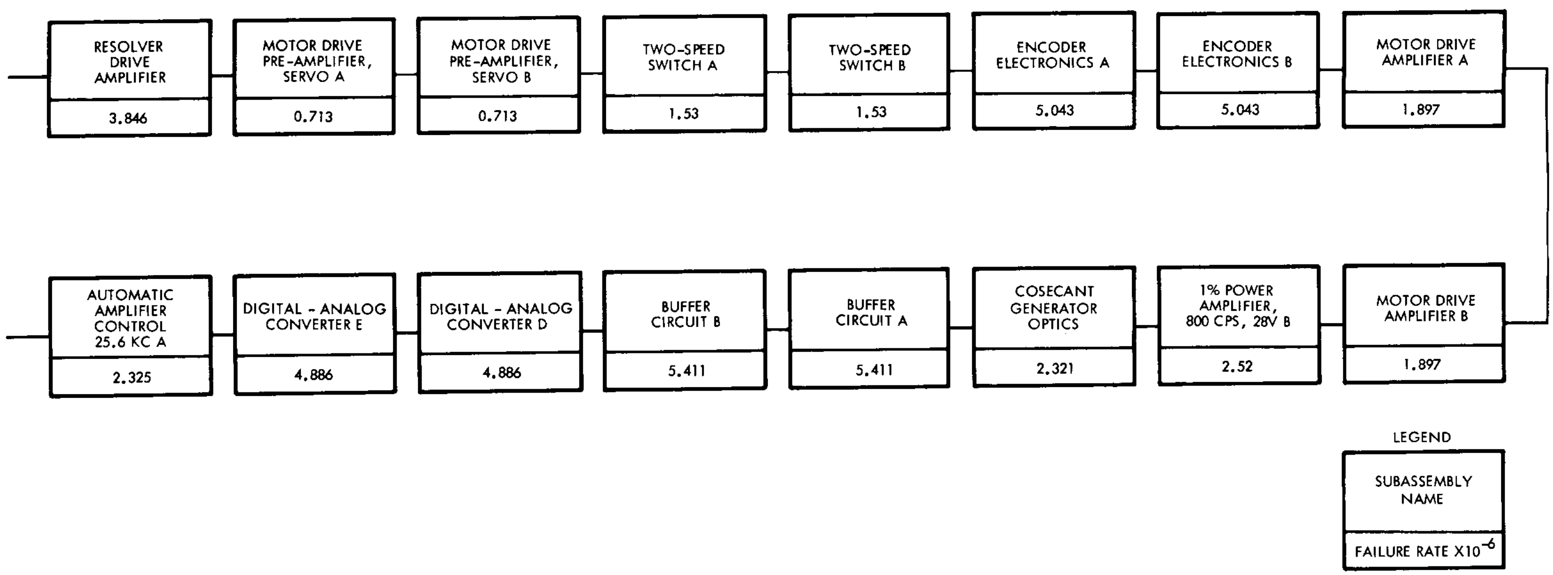


Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 8 of 13)

[redacted]

COUPLING DISPLAY UNIT

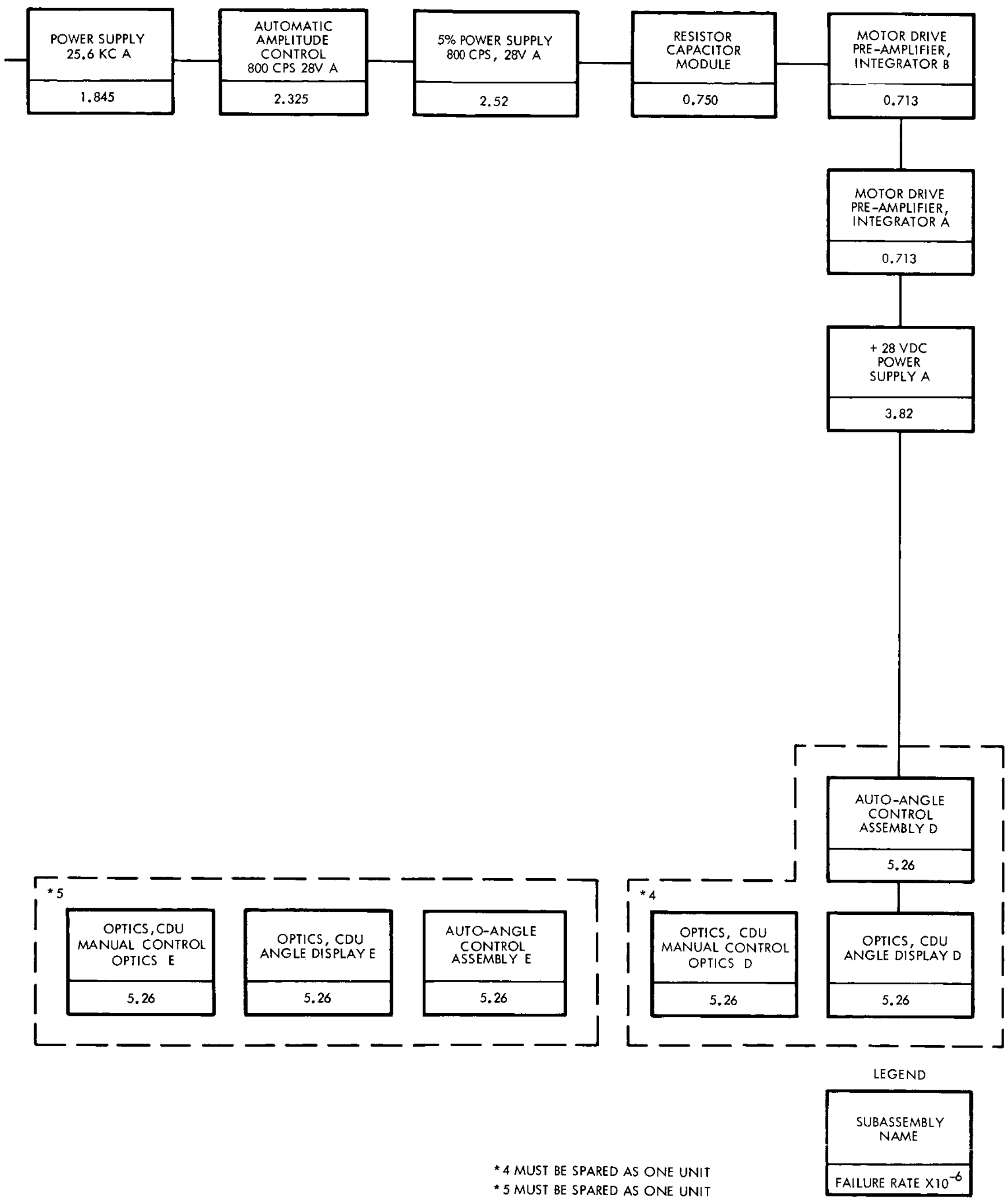


Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams

Apollo Guidance Computer (Sheet 9 of 13)

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SEXTANT

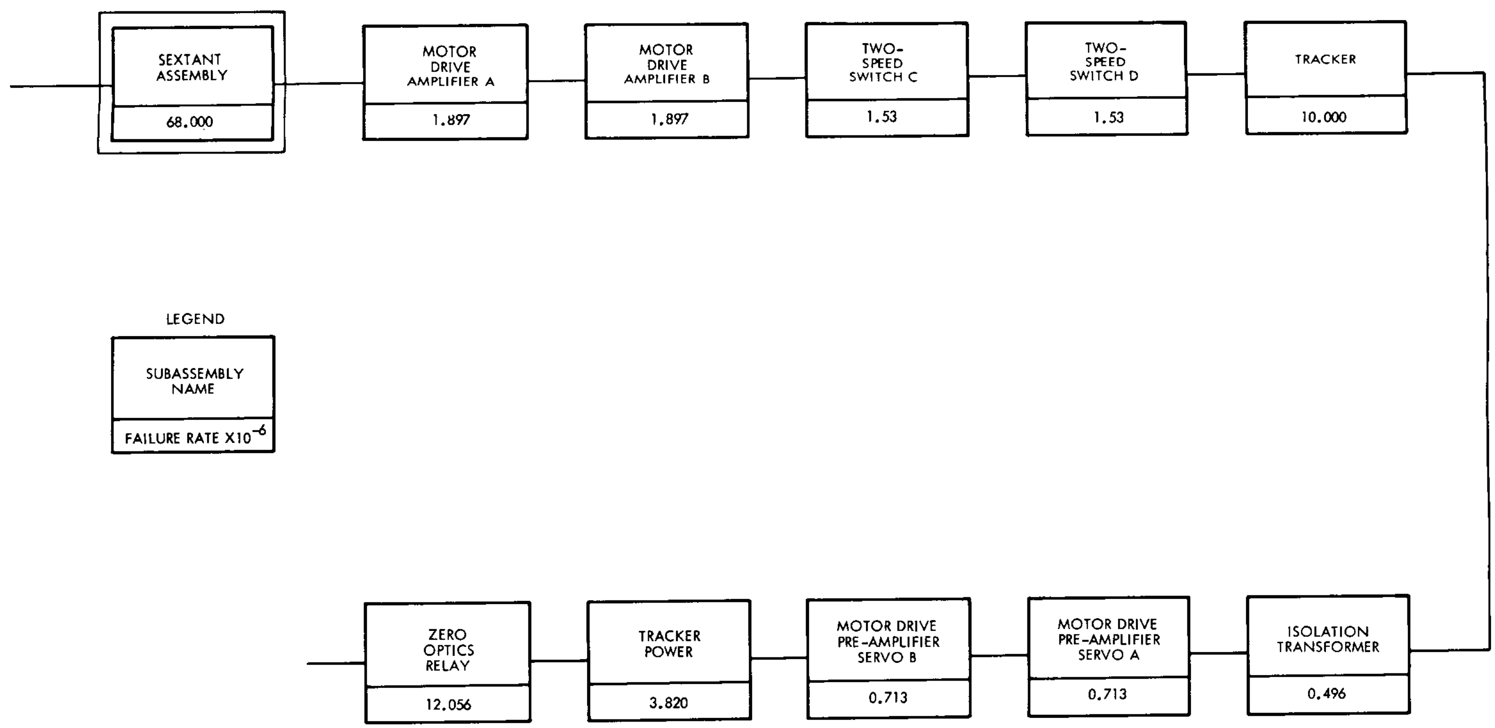

Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 10 of 13)

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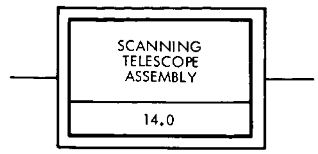
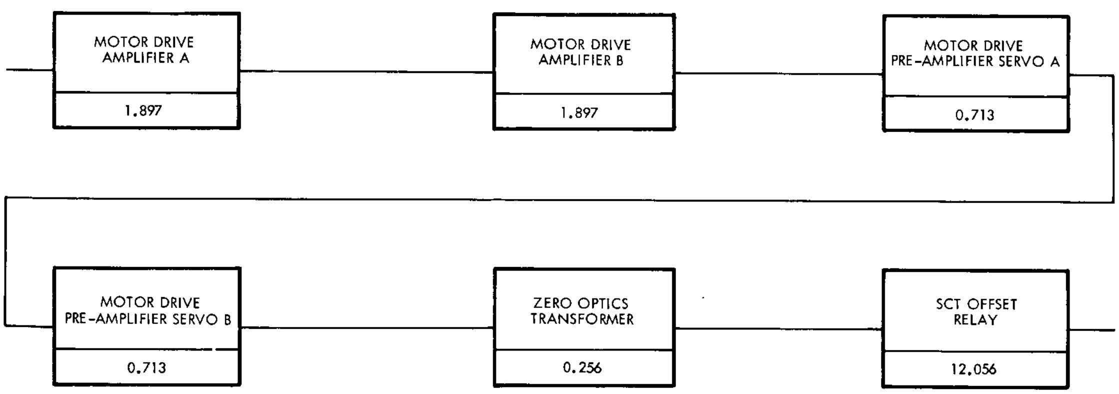
SCANNING TELESCOPE ASSEMBLY



SCANNING TELESCOPE ELECTRONICS



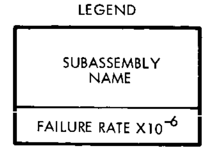


Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams Apollo Guidance Computer (Sheet 11 of 13)

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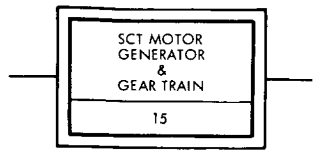
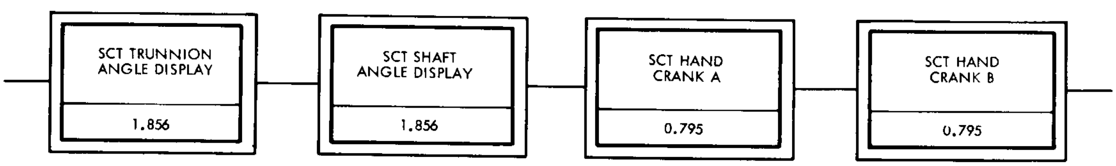
SCANNING TELESCOPE MOTOR DRIVE AND GEAR ASSEMBLY



SCANNING TELESCOPE HAND CRANK AND DISPLAYS



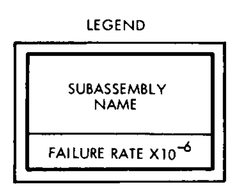


Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams
Apollo Guidance Computer (Sheet 12 of 13)

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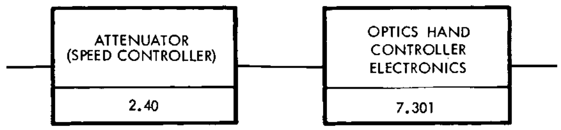
OPTICAL HAND CONTROLLER



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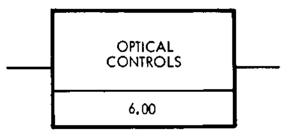
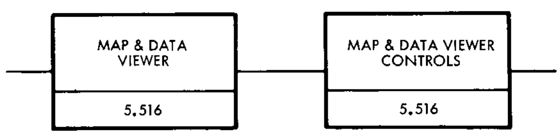
OPTICAL CONTROL PANEL



MAP AND DATA VIEWER ASSEMBLY AND CONTROLS



LEGEND

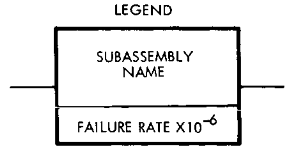


Figure 3-2. Guidance and Navigation Subassembly Logic Diagrams
Apollo Guidance Computer (Sheet 13 of 13)

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INSTRUMENTATION

SUMMARY

The primary efforts concerning the Instrumentation subsystem involved subcontractor evaluation and management. Various technical coordination meetings were attended, and Purchasing was supported during contract negotiations.

Studies were performed to determine the effects of instrumentation equipment on over-all spacecraft mission success and crew safety reliability. Determination of on-board displays allowed failure effects analyses to be performed, resulting in recommended design changes.

ANALYSIS

Central Timing Equipment

The first technical coordination meeting with Elgin was held early in this quarter. Reliability discussions resulted in instructions to Elgin regarding parts specifications, reliability predictions and identification and traceability.

Parts specifications have been received from Elgin and are presently being reviewed. Special consideration is being given to specifications for integrated circuits, the essential building blocks of the central timing equipment (CTE). Procurement of these devices have been limited to a single vendor, Texas Instruments. This selection was a result of evaluation of several vendors circuits and subsequent narrowing of the list of vendors to two potential suppliers, Texas Instruments and Signetics, Inc., because of inherent design limitations in the devices offered by the other companies. Signetics was visited by S&ID to obtain design and reliability information not previously published. The obtained material was evaluated and it appeared that, subject to actual test verification, the Signetics devices would allow the design and reliability requirements to be met. However, testing by Elgin revealed that the devices were subject to a failure mode intolerable in the CTE. Slight transients in the input of the circuits caused punch-through of the input speed-up capacitor. Corrective action, such as inclusion of a zener diode bypass, could not be initiated by the vendor early enough to support the CTE program.

Delivery of the first CTE engineering model is expected at the end of this quarter to be used on Boilerplate 14. Elgin's qualification test plan

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will be submitted for S&ID review at the beginning of the next quarter to support test initiation scheduled for December. Elgin's E model reliability prediction is due at this time and will be evaluated to determine conformance to the reliability requirement. It is expected that, upon review of the reliability documentation, a coordination meeting will be held early in the next quarter to resolve any problems that develop.

Apollo TV Camera

As a result of NASA and S&ID meetings, it was decided to design the TV camera for lunar surface operation. The TV procurement specification was revised to include design changes, e.g., incorporation of an internal oscillator and clock circuit with more stringent environmental criteria (7.5×10^{-10} mm Hg vacuum), and revised test criteria for better utilization of the hardware. A meeting was held with RCA to discuss the revised specification and offer S&ID clarification in order that RCA might submit a cost proposal on a cost plus fixed-fee basis. Specific direction was given RCA in all areas of question, including areas significant to reliability, such as parts approval, materials approval, analytical assessment of reliability requirements, environmental criteria, failure reporting, and qualification testing.

Because of the relatively high voltages associated with the TV camera, S&ID felt it necessary to require an additional test. The environmental criteria includes both the normal condition of 100-percent O_2 at 5 psia and the emergency condition of 10^{-10} mm Hg in case of meteoroid puncture or other causes of depressurization. There is, therefore, the possibility of corona discharge due to high potentials when passing through this pressure differential. A test was included to simulate this condition with the camera operating.

At the next meeting RCA submitted a proposal to S&ID for review and evaluation. RCA was asked to submit more details supporting the proposal, including task and subtask narratives, material justification, and labor time phasing. Upon receipt of this material, S&ID evaluated its validity and made independent estimates of time and materials required to design, develop, fabricate, and test the TV camera. Subsequently, contract negotiations were held both at RCA and S&ID, wherein the scope of work and contract price were definitized. An additional technical meeting was held at RCA which included a demonstration of the engineering evaluation camera to be used in crew compartment illumination and field-of-view studies. S&ID was well pleased with the performance of the camera and its similarity to final D model configuration. Ultimate design parameters were very closely approximated.

The camera is complete and delivery is expected prior to the end of the quarter. Parts specifications have been received from RCA and are presently being evaluated. Completion of the evaluation is expected before the end of the quarter to allow part procurement to support RCA's required delivery schedule. Efforts expected in the coming quarter include: evaluation of RCA's reliability prediction, materials review, test plan reviews, direction regarding expected changes in dynamic environments (a critical design problem area), review of RCA's failure mode and effects analysis, analysis of part stress levels utilized by RCA, and review and evaluation of additional required documentation.

In-Flight Test System

At present, the procurement of the in-flight test system (IFTS) equipment has not been completed. Studies are continuing, however, to determine the effect of the IFTS on the reliability of the Apollo electronics subsystems. Results of a typical study indicate that the presently predicted electronics reliability can be increased from 0.673 to 0.984, utilizing the IFTS and 86 pounds of on-board spares.

Alternative methods to achieve the required reliability were investigated. Redundancy of electronic components within a subsystem and utilization of all spare modules within a failed component (no IFTS) were analyzed to determine if either method would be an acceptable trade-off to an IFTS. The results indicate the desirability of including an IFTS from a reliability versus weight viewpoint. They are:

	Redundancy	Sparing Without IFTS	Sparing With IFTS
Δ weight in pounds to achieve 0.984 for Apollo Electronics	511	170	143

Apportionments have been established for a single comparator measurement and the voltmeter. They are 0.99988 and 0.99977, respectively. These values are based on preliminary designs and estimated duty cycles of the equipment. It appears that these requirements will be adequate to implement any required in-flight maintenance. This is primarily because even though the individual predicted numerics appear high, the voltmeter can be considered a back-up to any individual comparator. Although there are limitations to this concept, e.g., loss of automation and limitation of the self-test capability to determine whether a comparator has failed, the IFTS would not appreciably effect the probability of successful in-flight repair.

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Recovery Antenna Equipment

A field analysis was held at Airborne Instrument Lab (AIL), supplier of the recovery antenna equipment. The purpose of the analysis was to establish, in detail, the manhours required to implement a reliability program commensurate with Apollo objectives. This information was obtained and the resulting analysis is in progress.

AIL has requested a deviation from the numerical reliability requirement on the basis of its present prediction for the diplexer. The prediction is being evaluated to determine its validity. Methods will be investigated to augment the predicted reliability, and subsequently direction will be given to the subcontractor.

C-Band Antenna

Emertron, supplier of the C-band antenna, has submitted a revised cost proposal as the result of additional design and test requirements. Justification for these costs is being evaluated for validity. The additional test requirements are being evaluated to assure that only those tests are included that give meaningful qualification information.

High-Gain Antenna

The 2-kmc hi-gain antenna procurement specification was revised to reflect the latest design and environmental requirements. A specification negotiation was conducted with the supplier, Avien, Inc. The supplier contended that performance degradation would result from the more stringent requirements. Therefore, Avien requested deviation from the operational parameters during the reaction control system firing. S&ID will consider Avien's request upon formal submittal of justification, including predicted performance variations.

Parts and material analyses are being performed by the supplier and will be submitted during the next quarter. A finalized design and contract agreement is S&ID's prime objective during this period.

Controls, Displays, and Sensors

Meetings have been held with several potential suppliers of Apollo instrumentation during this quarter. The instrumentation equipment included electrical meters, switches, the mechanical clock, antenna diplexer, r-f connectors, heat flux transducers, and other measurement systems.

Many of the companies indicated confusion concerning the numerical reliability requirements of the procurement specifications. S&ID

[redacted]

emphasized that empirical demonstration by life testing is not intended. The requirement should be analytically demonstrated by a method derived by the supplier and approved by S&ID. S&ID stressed that of prime importance was design improvement as a result of failure mode analyses, testing, and analysis subsequent to failure. Quality control was emphasized by S&ID as being extremely important in the manufacture of these devices.

A study to apportion reliability to displays, controls, and sensors is in progress. This instrumentation, where applicable, will be apportioned reliability numerics from the system with which it is associated. In many cases, however, the instrumentation is not used in the normal management of a single system, and requirements must be established by other criteria. Numerical apportionment has proved impractical for this category of instrumentation. Contingency analyses based on failure modes have been initiated to determine effects of control, display, and sensor failures. Recommendations for display and sensor design changes have resulted from these analyses. Follow-up activity will continue throughout the next quarter, as will similar studies on controls and sensors not associated with displays.

TEST PROGRAM

VHF/2KMC Scimitar Antenna

Preliminary pattern tests were performed on a one-third scale model of the combined VHF/2KMC antenna mounted on the +Z and -Z axes of the one-third scale CM. The objective of these tests was to determine the optimum stations at which to install the antennas on the CM.

Control Console

Procurement specifications have been generated for securing bids on each subcomponent part and/or equipment going into the subpanel assemblies. Negotiations have been firmed for two component parts as a result of bids submitted on the released procurement specifications. Qualification tests for these two component parts have not been started, but it is expected that the schedule will be maintained without serious slippage. Concurrent with each contract award, a displays and controls (D&C) qualification test schedule is prepared to provide program visibility.

TV Camera

The vidicon camera tubes have been vibration tested during August 1963, at the RCA facility. No test data has been received at the time of this report.

GFE Instrumentation

In order to determine the qualification status of NASA-supplied instrumentation, a representative of S&ID obtained qualification test reports on some of the units. The remaining reports have not been received by S&ID. As a consequence, S&ID has asked for a deviation from the NASA requirement for a qualification status on BP6 vehicle equipment that are not covered by test reports on hand at S&ID.

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SUBCONTRACTOR MANAGEMENT

S&ID Reliability attended a meeting at RCA 29 July to 2 August. During this session, the exceptions to and interpretations of the TV camera procurement specification test programs were discussed. Interpretation of the test effort was mutually agreed upon by RCA and S&ID. The RCA cost proposal will reflect these interpretations, therefore, the level of test effort can be negotiated.

PLANNED ACTIVITIES

Based on past experience with aerospace equipment in the Mercury capsule, an effort is being made to qualify each subpanel assembly to a flight-simulated 100-percent oxygen environmental test. As a result of the last Mercury flight, it was found that certain components deteriorated quite rapidly under a combined environment of 100±5% oxygen at 80% relative humidity with 1% saline. Since it is quite probable that this condition may be encountered during the Apollo mission, the feasibility of testing D&C components in this combined environment will be investigated.

The following components will begin qualification testing during that period.

Component	Supplier
Low-pass filter	RANTEC
Type I recovery antenna	AIL
Type II recovery antenna	AIL
Diplexer for the recovery antenna	AIL
2KMC antenna switch	TRANSCO

Development testing will begin on the 2KMC high-gain and C-band antenna systems.

STABILIZATION AND CONTROL

SUMMARY

Detailed reliability analyses are progressing with the receipt of detailed design data on the mechanization of the stabilization and control system. Rigorous investigations have been and are presently being performed on the stabilization control system to determine if the present design can meet the reliability requirement. Deficiencies have been noted and corrective action has been taken.

ANALYSIS

Engine Thrust Control Circuit

An analysis of the engine thrust control circuit was performed to determine the ability of the circuit to meet the mission-success and safe-abort requirements. A failure mode and effects analysis was also performed to determine if two single failures would preclude the ability to perform a safe abort. This condition did exist; therefore, an equivalent circuit was designed by S&ID to meet all of the design and reliability requirements. The failure mode and effects on both circuits are shown in Table 3-6.

Table 3-6. Failure Mode and Effects Engine Thrust Control Circuits

Circuit	Mode	Effect	Action
M-H	Open	Continuous engine firing	ΔV direct off
	Close	Engine cutoff	Catastrophic
S&ID	Open	Cannot fire in particular mode	Use other ΔV mode
	Close	No effect on firing	None required

In conjunction with the failure mode and effects analysis, studies were made on failure rates, weight, and complexity. The results are noted as follows:

Failure rate - S&ID circuit shows a 65.98-percent decrease
Weight - S&ID circuit shows a 73.33-percent decrease
Complexity - S&ID circuit shows a 66.15-percent decrease

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Spares

The results of the second preliminary spares study is now available for AFRM 011. The following list shows the subassemblies spared and the weight of the spares.

Mode select relay package	0.85
Mode select switch package	0.90
G&N - BMAG demodulator amplifier	0.80
Rate stick demodulator amplifier	0.80
Thrust vector control summing amplifier	0.80
Electronic control assembly auxiliary power supply	0.80
Logic - G&N pulse train	0.80
Total spares weight (lbs)	5.75

Parameter Variation and Stress Analysis

A parameter variation and stress computer analysis is being performed on the operational d-c amplifier utilized extensively in the stabilization and control subsystem. Because of the delay in receiving the information required for performing this analysis and the limited amount of data, the schedule for performing these analyses has been delayed.

PROBLEM AREAS

Minneapolis-Honeywell is required by SCS Procurement Specification, MC 901-0012C, paragraph 3.1.11.5 to use S&ID-approved high-reliability parts in mission essential flight hardware. M-H has submitted part specifications to S&ID for approval as nonstandard parts and material, per MIL-E-5400. These specifications have been reviewed by S&ID, and the required changes necessary for S&ID approval have been sent to M-H. M-H has taken exception to these changes, stating "there were no requirements on part specifications, other than to insure the high reliability of the end item." This is contrary to the SCS Procurement Specification. S&ID will not approve M-H part specifications unless they are changed to be compatible with S&ID parts specifications or unless M-H uses S&ID part specifications.

M-H has stated "the differences (in the part specifications) must be worked out." It is evident that M-H is lagging behind in the acceptance of S&ID part specifications and of S&ID responsibility for approving high-reliability parts. If this attitude persists, the results will be an astronomical increase in cost and a severe schedule slippage, since S&ID cannot take the responsibility of accepting end-item mission essential

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flight hardware built with M-H nonapproved parts. An effort will be made to reach agreement with M-H concerning the S&ID part philosophy during a meeting scheduled in the next quarter. The purpose of this meeting is to review M-H's reliability effort for the Apollo program. Should this effort fail, further action must be initiated by S&ID to alleviate this problem in its entirety.

TEST PROGRAM

The following is a status of SCS development and qualification test activity.

Sensor Development Tests

Development testing of the DGG 245 attitude gyro is essentially complete. Subassembly life tests of gyro components were successfully completed with the test samples compiling from eleven to fifty-two thousand hours of operation without failure. Early in the program, a spin motor running detector coil failure resulted in a redesign of the detector coil. Subsequently this component completed eleven thousand hours of testing without failure. Design proof (development) testing of six attitude gyros under temperature and vibration produced only two failures: one was a shorted sensor, which was corrected by a process change, and the other, a failure of a spin motor to start, which required no corrective action because the failure occurred after exceeding the gyro 1600-hour life requirement. Development tests of the DGG 177 accelerometer were initiated late in the quarter, and testing of the MS 137 rate gyro, delayed by production yield problems, is scheduled to begin during the next quarter. Thermal and vibration testing of the rate gyro package and attitude gyro, accelerometer package have disclosed minor insulation and vibration damping problems that are currently under investigation.

Electronic Control Assembly Development Tests

The breadboard testing of the initial SCS design is essentially complete. Some breadboard evaluation of design changes will be required throughout the program, however. Thermal and vibration testing of ECA card mock-ups has been completed and testing of actual ECA hardware is scheduled to begin during the next quarter.

Displays and Controls Development Tests

Vibration, temperature, and vacuum testing was satisfactorily completed on switches and potentiometer and meter movements of the display subsystem. Vibration of a flight direction attitude indicator (FDAI) mock-up was completed, and at the end of this report period a new pistol-grip rotational control was undergoing acceleration tests.

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Parts Testing

M-H reports that parts selection for the initial design is complete, thereby completing application suitability testing; however, part specification problems yet unresolved between M-H and S&ID may necessitate additional evaluation tests. Qualification testing of relays and transformer is continuing at M-H.

Component and Subsystem Qualification Tests

No component (black box) and subsystem qualification tests were completed during the quarter, nor are any planned for the next report period.

SUBCONTRACTOR MANAGEMENT

A reliability coordination meeting was held 18-21 June 1963, with Minneapolis-Honeywell. Discussed were parts specifications, substitute parts, part testing, and production areas. With a few exceptions, part specification problems were resolved during this meeting. After obtaining 100-percent agreement on the parts and specifications, they will be given to M-H purchasing personnel to determine the change-over impact on cost and schedule.

M-H was asked to justify its planned lot sampling and 100-percent part tests prior to usage. A sample of the tests performed was also requested. M-H stated that periodic vendor quality audits were planned. S&ID indicated that M-H would receive official direction to maintain 100-percent source inspection at the vendor.

M-H presented its production process for the movement of parts and components throughout subsystem manufacturing. The potting area was found to be inconsistent with the requirements of the specification and parts. This area should be a clean, controlled area. The parts storage area was not controlled either. S&ID requested that M-H review the vendor controls in its manufacturing and storage areas.

M-H stated that, because of high-reliability parts procurement fabrication schedules, it was considered impossible to have 100-percent high-reliability parts in flight worthy systems through AFRM 011. S&ID will give M-H an answer to this problem.

During a reliability coordination meeting 1 and 2 August 1963, M-H parts specifications nonconformity with S&ID requirements were discussed in detail. Direction had previously been given to M-H regarding parts specifications. S&ID stated that approval would be given upon implementation of this direction. Partial agreement was also reached on the M-H Program Plan A62 751E1(3). Most areas of discrepancies were resolved in the meeting.

Another area that was discussed was the submission of failure reports to S&ID. It was resolved that M-H shall submit failure reports to S&ID on all failures of Apollo SCS flight items and bench maintenance equipment discovered during development, qualification, and acceptance test except as follows:

1. Failure of an item below the "card" or major subassembly level will not be reported. Examples of the lowest reportable levels of assembly are attitude gyro, rate gyro, acceleration gyro, torquing amplifier card, switching amplifier card, thrust vector controi integrator card, mode select logic card.

2. Failure of an item because of physical nonconformance to the applicable M-H drawing will not be reported.

3. Failure of BME, other than during acceptance and qualification testing will not be reported.

Directives

The following directives were requested through the cognizant S&ID department.

M-H should be directed to delete its requirements for incoming part inspection and acceptance testing prior to usage. M-H parts handling procedures were considered to be detrimental to the attainment of high reliability due to excessive handling and testing. The assurance of high-reliability parts will be placed at the vendor with the requirement of 100-percent source inspection. M-H should be directed to use lot serialization in lieu of part serialization to meet its traceability requirements, if it so elects.

The area in which encapsulation of the completed module takes place must be an environmentally controlled, clean area, as stated in NCP 200-2. High-reliability electronic parts, which are not in hermetically sealed containers, are to be placed in an environmentally controlled area.

Since parts procurement procedures play a major role in sustaining design integrity, M-H adherence to S&ID parts specifications is required in order that attainment of the high-reliability requirements of the SCS

[redacted]

will not be jeopardized. Because failure reporting and corrective actions provide design integrity data, it is mandatory that M-H observe the provisions of SID 62-11 and NCP 200-2.

PLANNED ACTIVITIES

Plans have been made to continue studies on M-H circuits. As a result of the studies, it may be possible to simplify the SCS subsystem, increase the reliability, decrease the weight, and redesign all failure modes that will preclude the ability to perform a safe abort. Work on parameter variation and stress analysis will be continued. Work initiated on AFRM 009 will continue. Logic diagrams will be completed for the entire mission. A reliability number will be apportioned to the flight programmer. Design and testing of the programmer will be monitored to make sure that it will meet all of its objectives.

Testing activity will continue.

An evaluation and subsequent negotiation of the M-H "delta" cost proposal to cover program changes since the original December quote will be made during the next quarter. Support will be furnished for all engineering, reliability, and production areas.

Effort will be made to alleviate certain problem areas that exist in the qualification program, i.e., scope of checkout, sparing, failure philosophy. Qualification program optimization in light of Master Development Schedule 7 will be explored.

[redacted]

[redacted]

IV. GROUND SUPPORT EQUIPMENT ANALYSIS

SUMMARY

Failure mode and effects analyses performed on ground support equipment during the report period are shown in Table 4-1.

Table 4-1. Ground Support Equipment - Failure Mode and Effects Analyses

Unit	Nomenclature	Category*
C14-191	Terminal distributor unit	MSE
C14-029	Launch escape sequencer, BME	MSE
A14-001	Launch escape tower substitute unit	MSE
A14-003-101	Pyrotechnics initiator substitute unit	MEE
C14-019	Test conductor console unit	MEE
A14-021	Launch vehicle substitute unit	MSE
S14-007	Contamination prevention unit	MEE
S14-026	LH_2 transfer unit	MEE
S14-032	LO_2 transfer unit	MEE
S14-052	Water-glycol cooling unit	MEE
C14-051	Pyrotechnics bench maintenance equipment	MEE

*Note: MSE designates Mission Support Equipment
MEE designates Mission Essential Equipment

[redacted]

Reliability predictions performed on ground support equipment during the report period are shown in Table 4-2.

Table 4-2. Ground Support Equipment - Reliability Predictions

Unit	Nomenclature	Category	Design Goal	Predicted MTBF
C14-135	Signal conditioner	MSE	300	1737
A14-003-001	Pyrotechnics initiator substitute unit	MEE	600	1142
C14-191	Terminal distributor unit	MSE	300	2289
A14-001	Launch escape substitute unit	MSE	300	1767
A14-001-101	Launch escape substitute unit	MSE	300	1638
C14-029	Launch escape sequencer, BME	MSE	300	783
S14-057	RCS oxidizer service unit	MEE	600	2152
S14-063	SM RCS fuel servicing unit	MEE	600	2152
S14-064	CM RCS fuel servicing unit	MEE	600	2152
A14-011	Ground cooling cart	MSE	300	1287
C14-075	Propulsion system C/O group	MEE	600	955
A14-019	Disconnect set	MEE	600	2304
A14-024	Disconnect set	MEE	600	2304
S14-001	Module leak test unit	MEE	600	3824

Reliability effort on MEE (mission essential equipment) in support of each boilerplate and AFRM has been coordinated and is up to date with the Development Schedule No. 7 Figure 4-1 illustrates the status of the MEE (mission essential equipment) and critical MSE (mission support equipment) reliability analysis for each spacecraft. Analysis performed on each successive spacecraft will be used to update the successive MEE and MSE analyses. There is an increase in the amount of MEE, from three units on Boilerplate 6 to approximately fifty units on Airframe 011. Reliability figures have been calculated for the countdown period, using failure rate data obtained from the reliability prediction on each boilerplate and AFRM. This procedure, along with test assessment data, furnishes a periodic check of the reliability realization for each boilerplate and AFRM, and will be used as an aid in support of AFRM 011. As Figure 4-1 indicates, the GSE reliability analysis for Boilerplates 6 and 12 has been completed, and is in process for Boilerplate 13.

ANALYSIS

The following analyses are performed on electrical, electromechanical, and mechanical circuits to ensure that proper design consideration is given to all elements contributing to mission success or crew survival.

1. Failure mode and effect analysis studies are performed on all mission-essential equipment to determine critical failure modes that would result in GSE-induced failures in the spacecraft or GSE equipment failing to detect a spacecraft failure. As a result of these studies, recommendations are made concerning the design. Table 4-3, Failure Mode and Effect Analysis-GSE, defines in general terms the criticality, corrective action, and failure mode classification.

2. A computer-aided Mandex d-c analysis is performed on all mission-essential electronic circuitry to determine stress conditions and failures that can occur because of poor design. The stress analysis is used to calculate a predicted reliability number in terms of failure rate by applying the stress parameters obtained to derating factors and failure rate application.

3. A preliminary reliability prediction analysis is performed on all auxiliary, checkout, and servicing equipment. These analyses are performed during the initial design stages, and the failure rate data are presented on the system, subsystem, and component level. Failure rate data presented in these analyses represent the latest state of the art failure rates currently in use in the

[redacted]

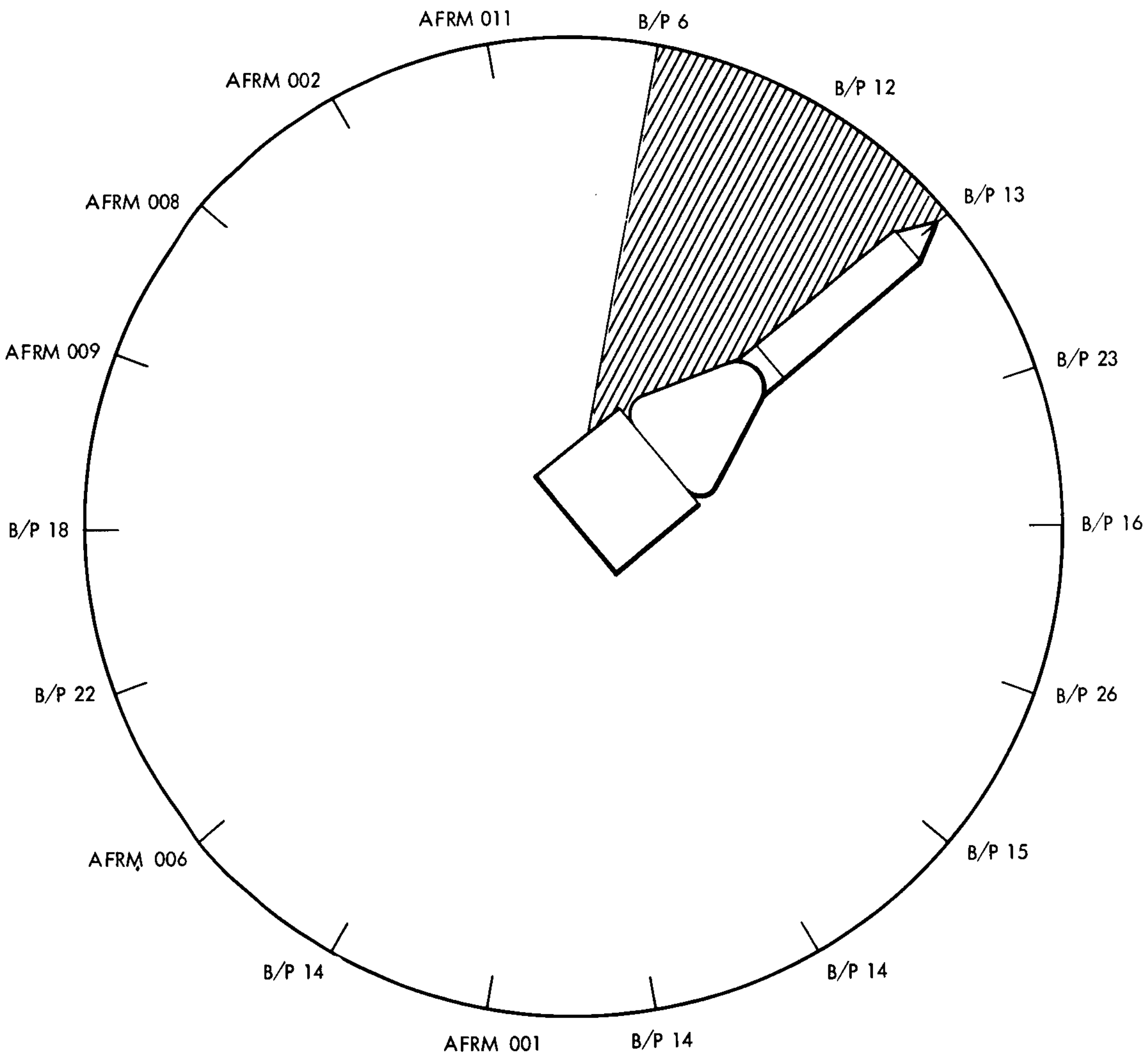


Figure 4-1. Mission Essential Equipment GSE Support

Table 4-3. Failure Mode and Effect Analysis - GSE Criticality, Corrective Action, and Failure Mode Classification

Criticality Categories	Failure Mode Order	Corrective Action Classification (CAC)
Catastrophic	First-Order Failure Mode. Failure of a GSE component which results in personnel hazard or a spacecraft failure, detected or undetected. Loss of equipment by damage.	Unit will be out of service, and will be removed from work area while failed component is being replaced.
Major	Second-Order Failure Mode. Failure of a GSE component which results in extended delay of servicing or checkout function.	Unit will be out of service while replacement or repairs are being made. It may be necessary to remove unit from work area.
Minor	Third-Order Failure Mode. Failure of a GSE component which results in temporary delay of servicing or checkout function.	Minor adjustments or repairs will be made while the servicing or checkout function continues. It will not be necessary to remove unit from work area.
All others	Fourth-Order Failure Mode. Failure of a GSE component which results in no delay in servicing or checkout function.	No corrective action required until servicing or checkout function is completed.

[redacted]

missile and space industry. The analyses, when presented to GSE design personnel, serve as a guide for reliability improvements.

FAILURE MODE AND EFFECT ANALYSIS

The main purpose of the failure mode effect analysis technique is to ensure that the design of the Apollo ground support equipment is inherently reliable. The purpose of the analysis is to identify and remove from the dynamic components of all GSE systems all first order failure modes that could cause a personnel hazard, cause undetectable damage to the spacecraft, result in failure to detect a spacecraft malfunction, or increase the probability of accepting bad or rejecting good spacecraft equipment during prelaunch checkout. These analyses will provide the following information and requirements:

1. Identification of failure modes, failure interactions, and effects of these potential failures on the ground support equipment and the spacecraft

2. Fail-safe requirements for GSE components

3. Failure mode cause analysis requirements

4. Reliability recommendations in the initial stages of design

5. Criteria for GSE and component review by the Design Review Board

A prime function of this analysis is to determine if there are any single failures which cause first-order failure modes. A secondary function is to define second-order failure modes that are undetectable. The ultimate is to achieve a system design that has neither first-order failure modes nor undetectable second-order failure modes.

Test Conductor Console - C14-019

A failure mode and effect analysis was performed on the test conductor console equipment. This equipment will be used to centralize all monitoring and control of system functions during prelaunch operations and during launch countdown for Boilerplates 6, 12, and 23.

[redacted]

An evaluation of the functional operating requirements of this unit indicates that the launch control subsystem was the most critical of its subsystems since failures in the pyro bus switches could result in an on-pad delay; these failure modes are classified as second-order failures. Twelve separate failure modes that could exist in this equipment were examined and all are classed as second-order detectable failure modes. These modes of failure are summarized in Table 4-4.

The two component failure modes that could occur are as follows:

1. Pyro Bus switch S4 fails open and fails to actuate the launcher motor.

2. Pyro Bus switch S3 fails closed causing the launcher motor to stay in readiness.

Redesign to eliminate these failure modes is not recommended because the failures are readily detectable, because the unit and its components have a high degree of operational reliability, and because any failures in the switches would only result in a short delay in countdown.

Pyrotechnics Initiator Substitute Unit A14-003-001

A failure mode and effect analysis was performed on the pyrotechnics initiator substitute unit. This equipment will be utilized to simulate the pyrotechnic initiators by interfacing with the pyrotechnic firing system, exhibiting the proper impedances, measuring the system outputs, and transmitting signals indicative of the adequacy of the measurements to the GSE. The equipment will be used in all phases of the test operations including on-pad countdowns. This configuration will be used on Boilerplate 12.

An evaluation of the functional operating requirements of this unit indicates that the most serious failure mode in this unit would be a failure of relay K to open. This would short the pyro battery to ground through a high resistance and would eventually drain the SC pyro battery. This failure is classified as a first-order failure mode. Eight likely failure modes were examined; these are summarized in Table 4-5.

The component failure rate is extremely low and will not be subject to transients; the pyrobatteries will be monitored, therefore, redesign is not warranted.

Table 4-4. Failure Mode Effect Analysis Summary Test Conductor Console - C14-019

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		12				12			12	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS		12				12				
SUM TOTALS	12				12				12	

Table 4-5. Failure Mode Effect Analysis Summary Pyrotechnics Initiator Substitute Unit - A14-003-001

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	1					1			1	
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.		7				7			7	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS	1	7				8			8	
SUM TOTALS	8				8				8	

Pyrotechnics Bench Maintenance Equipment (C14-051)

A failure mode and effect analysis was performed on the pyrotechnic bench maintenance equipment. This equipment will be utilized to measure the resistance of the hot-bridge wire squibs before the squibs are installed in the spacecraft.

An evaluation of the functional operating requirements of this unit indicate that the only serious failure modes that could occur in this equipment would be those that would permit the acceptance of a faulty pyrotechnic device and, consequently, result in an aborted or downgraded mission. These types of failures are classified as first-order failures. Eighteen separate failure modes that could exist in this equipment were examined and eight first-order failure modes could occur during the checkout of a pyrotechnic device. These modes of failure are summarized in Table 4-6.

All 8 first-order failure modes involve component failures that could result in a condition that would allow faulty squibs to be accepted. Redesign to eliminate the first-order failure modes is not considered justifiable because of the extremely low-failure rates associated with the unit. The following recommendations were made:

1. Operational test procedures should be written to cover the operation and use of Model C14-051

2. Precision resistors should be used for self-check purposes in the equipment.

Water Glycol Cooling Unit (S14-052)

A failure mode and effect analysis was performed on the water-glycol cooling unit. The analysis covers the operation of the cooling unit during the period of t -6 hours to t -15 seconds.

An evaluation of the functional operating requirements of this unit indicates that the most serious failure mode would be those permitting foreign particles, liquids, or vapors to contaminate the media. These failure modes during the launch cycle would be detrimental to the ECS performance during the mission. This type of failure mode is defined herein as being of first-order. Likely failure modes were examined. These modes, which are summarized in Table 4-7, reveal three undetectable first-order failure modes, which could occur during launch cycle.

[redacted]

Table 4-6. Failure Mode Effect Analysis Summary Pyrotechnics BME - C14-051

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	8				8				8	
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in minor adjustments or maintenance.				10				10	10	
TOTALS	8			10	8			10		
SUM TOTALS	18				18				18	

[redacted]

[redacted]

Table 4-7. Failure Mode Effect Analysis Summary Water-Glycol Cooling Unit (S14-052)

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	3				3					3
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.		4	2		2	4			6	
Detectable failure of a GSE component which results in its replacement or repair.		5	9			7	7		14	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.										
TOTALS	3	9	11		3	11	7		20	3
SUM TOTALS	23				23				23	

[redacted]

1. Media contaminated with foreign solids

2. Media contaminated with foreign solutions or gases

3. Loss of cabinet pressurization

Design restraints recommended to remedy these three failure modes were:

1. Filtering system redundancy to eliminate foreign particles.

2. Adding sensors to detect liquid/gas contamination.

3. Qualification testing to prove cabinet sealing design.

The analysis also reveals four undetectable second-order failure modes. The remedial restraints for these are identical to those listed for the first-order failure modes.

Pressurizing Contamination Prevention Unit (S14-007)

A failure mode and effects analysis was performed on the pressurizing contamination prevention unit. The analysis covers the operation of the unit during the servicing operation of the SC fuel and oxidizer tanks.

As shown in Table 4-8, 131 failure modes were examined. The analysis worksheets indicated that the most serious undetectable first-order failure mode would be at the source of tankage connection should the solenoid or check valves fail. At this point, there is no way of knowing whether the failure has occurred at tankage hook-up or down-stream in the system.

There were twenty-two failure modes classified as catastrophic based on the effects of GN_2 leakage or blocking, which will cause pressure loss or stoppage; both conditions introduce possible personnel hazard or loss of equipment by damage.

Recommendations made to the cognizant S&ID group were:

1. To provide the pressurizing contamination prevention system with dry GN_2, moisture content not greater than 1 ppm (-105 F dew point) and eliminate the water adsorber regenerative subsystem. The desiccant silica gel may emit residual substances that would contaminate the GN_2 and possibly clog the filtration subsystem, resulting in a delay or interruption of the servicing operations.

[redacted]

Table 4-8. Failure Mode Effect Analysis Summary Pressure Contamination Prevention Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	22				23					12
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.										
Undetectable failure of a GSE component which results in its replacement or repair.		29	30			53			11	24
Detectable failure of a GSE component which results in its replacement or repair.		18	8			25	1			17
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				24			5	24	2	2
TOTALS	22	47	38	24	23	78	6	24	13	55
SUM TOTALS	131				131				68	

[redacted]

2. To incorporate sensory devices throughout the system for monitoring various sections of the system in order to localize trouble spots and malfunctioning components. A proper check should be made at critical points in the system, particularly at the tankage fill inlet and exhaust outlet, and the media should be checked after passage through the water adsorber regenerative cycle.

LH_2 and LO_2 Transfer Units (S14-026 and 032)

A failure mode and effect analysis was performed on the LH_2 transfer unit. Due to similarity in design, this analysis is also applicable to the S14-032 LO_2 transfer unit. The analysis was made from available preliminary schematics provided by the vendor, the Cosmodyne Corporation, and covers the operation of the units during the provision of cryogenic fluid service to the SC fuel cells.

As shown in Table 4-9, 119 failure modes were examined. These include six solenoid valve failure modes, two pump-varidrive and two quick-disconnect failure modes that fell into the first-order failure mode category. To decrease these failures, it was recommended that the vendor use solenoid valves with Kel-F valve seats and high-reliability pump-varidrives plus quick-disconnect units that meet Apollo procurement specification requirements.

The analysis also determined that there were seventeen solenoid valves, four subcoolers, and eight filter failure modes that fell into the second-order failure mode category. It was recommended that the vendor use Kel-F valve seats for the solenoid valves and high-reliability subcoolers and filters to correct second-order failure mode possibilities.

A survey has been conducted on failure modes typical in the valve family operating in cryogenic applications. It was found that the valve family operates reliably when equipped with Kel-F seats and packing. Kel-F has the same physical characteristics as Teflon; however, the use of Teflon for the same purposes has shown high-failure rates due to its low elasticity at low temperatures (-250 to -470 F).

APOLLO DESIGN REVIEW

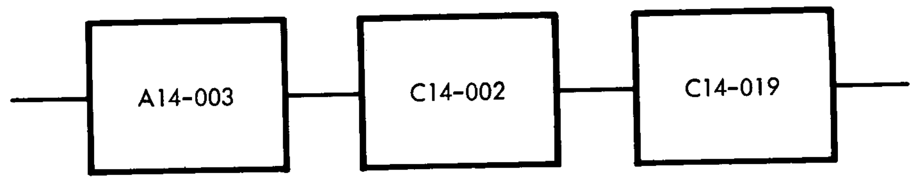
A briefing on spacecraft mission-essential GSE status was presented to NASA/MSC on the following boilerplates:

Boilerplate 6 - Mission Essential Equipment

The three models of MEE in support of Boilerplate 6, as shown in Figure 4-2, reflected a reliability of 0.986 based on a 4-hour countdown. The objective of its mission is early qualification of the launch escape

[redacted]

[redacted]



$$R = e^{-(\lambda_1 t_1 + \lambda_2 t_2 + \lambda_3 t_3)} = 0.986$$

MODEL NO.	TITLE	FAILURE RATE, λ (HR)
A14-003	PYROTECHNICS INITIATORS SUBSTITUTE UNIT	$0.8664/10^3$
C14-002	BAROMETRIC SWITCH TEST UNIT	$1.6667/10^3$
C14-019	TEST CONDUCTOR CONSOLE	$1.1074/10^3$

TIME OF INTEREST (t) = 4 HR

Figure 4-2. Boilerplate 6 Mission Essential Equipment

[redacted]

Table 4-9. Failure Mode Effect Analysis Summary (S14-026) LH_2 Transfer Unit and S14-032 LO_2 Transfer Unit

Criticality Classification	Failure Mode Order				Corrective Action Classification				Failure Effect Operation	
	1	2	3	4	1	2	3	4	Delays	Halts
Undetectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	2				2					2
Detectable failure of a GSE component which results in spacecraft failure, personnel hazard, or loss of equipment by damage.	8				5	3				8
Undetectable failure of a GSE component which results in its replacement or repair.										
Detectable failure of a GSE component which results in its replacement or repair		32	21			32	21		42	
Undetectable or detectable failure of a GSE component which results in minor adjustments or maintenance.				56				56		
TOTALS	10	32	21	56	7	35	21	56	42	10
SUM TOTALS	119				119				52	

[redacted]

system (LES). A 600-hour MTBF minimum reliability requirement has been assigned to model C14-002 for this demonstration. Although the design of this model has not been completely resolved, the equipment presently being used would suffice for this launch.

Boilerplate 12 - Mission Essential Equipment

The five models of MEE in support of Boilerplate 12, as shown in Figure 4-3, reflected a reliability of 0.974 based on a 6-hour countdown. The objective of its mission is early qualification of the launch escape system (LES) and maximum q abort.

Reliability assessment evaluation will be obtained on models A14-003, C14-002, and C14-019 from the tests on Boilerplate 6 to justify over-all reliability. In addition, reliability information will be obtained on models C14-051 and C14-112. An increase in mission reliability could be predicated on a complete reliability prediction and analysis on model C14-002. The over-all reliability figure will be modified and updated to reflect the latest configuration on model C14-002.

Boilerplate 13 - Mission Essential Equipment

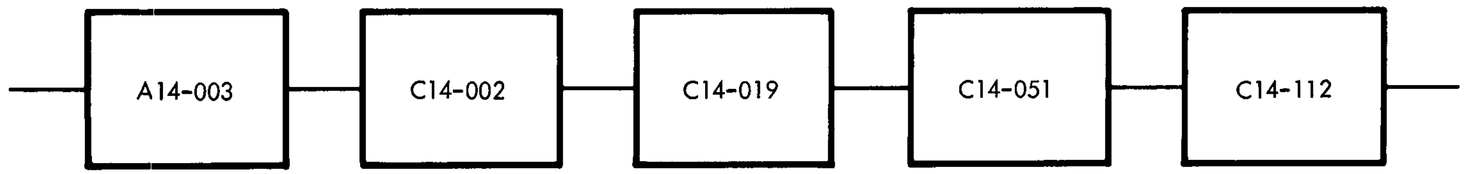
The six models of MEE in support of Boilerplate 13, as shown in Figure 4-4, reflected a reliability of 0.957 based on a 6-hour countdown. The objective of its mission is to qualify the launch vehicle and to demonstrate the physical and flight compatibility of the launch vehicle and SC. A reliability evaluation has been completed on models A14-024 and S14-052-101. A minimum reliability requirement of 600 MTBF has been assigned to models A14-003-201, C14-177, C14-180, and C14-414, pending final reliability analysis. The over-all reliability figure will be modified and updated pending the latest configuration on the above mentioned models. Therefore an improvement in reliability could be expected upon completion of these analyses.

SPECIAL STUDIES

The following special studies, covering the investigation of labor savings of analysis were completed.

Computer Programs

The computer program known as "CODE" (Computer derived equations), discussed in the 6th Quarterly Report, has been modified for use with the Recomp computer. The program is fully developed and will be used for the analysis of electronic circuits. The Recomp computer is used in this



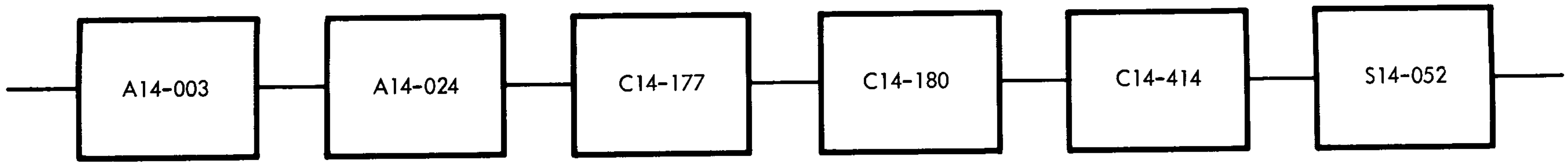
$$R = e^{-(\lambda_1 t_1 + \lambda_2 t_2 + \lambda_3 t_3 + \lambda_4 t_4 + \lambda_5 t_5 + \lambda_6 t_6)} = 0.974$$

MODEL NO.	TITLE	FAILURE RATE, λ(HR)
A14-003	PYROTECHNICS INITIATORS SUBSTITUTE UNIT	$0.8664/10^3$
C14-002	BAROMETRIC SWITCH TEST UNIT	$1.6667/10^3$
C14-019	TEST CONDUCTOR CONSOLE	$1.1074/10^3$
C14-051	PYROTECHNICS BME	$0.1673/10^3$
C14-112	RADAR TRANSPONDER & RECOVER BEACON C/O UNIT	$0.6378/10^3$

TIME OF INTEREST (t) = 6 HR

Figure 4-3. Boilerplate 12 Mission Essential Equipment

[redacted]



$$R = e^{-(\lambda_1 t_1 + \lambda_2 t_2 + \lambda_3 t_3 + \lambda_4 t_4 + \lambda_5 t_5 + \lambda_6 t_6)} = 0.957$$

MODEL NO.	TITLE	FAILURE RATE, λ(HR)
A14-003-201	PYROTECHNICS INITIATORS SUBSTITUTE UNIT	$1.6667/10^3$
A14-024	DISCONNECT SET, UMBILICAL, FLUID & ELECTRICAL	$0.4341/10^3$
C14-177	ELECTRICAL CABLE SET (AMR)	$1.6667/10^3$
C14-180	ELECTRICAL CABLE SET (AMR)	$1.6667/10^3$
C14-414	LAUNCH CONTROL GROUP	$1.6667/10^3$
S14-052-101	WATER-GLYCOL COOLING UNIT	$0.2379/10^3$

TIME OF INTEREST (t) = 6 HR

Figure 4-4. Boilerplate 13 Mission Essential Equipment

program to write the matrix equations, which are then programmed into the IBM 7090 computer. The use of this program will result in a time saving of 30 percent in performing circuit analysis.

GSE TEST PLAN

A proposal in the form of a briefing was presented to NASA in Houston on 23 July 1963. The proposal consisted of the GSE qualification program as defined by S&ID.

After this presentation, NASA requested S&ID to evaluate an integrated S&ID-Grumman GSE qualification plan and submit a budget and planning estimate for the testing. A procedure was drawn up for the budget and planning estimate according to the following MSC documents: MSC-E-1 "Apollo GSE Environmental Criteria," 7 August 1963, and MSC-GSE-1 "GSE Environmental Implementation and Qualification Criteria," 19 August 1963. The procedure consists of the following ten activities:

1. Equipment definition. Preparation of the most recent available list of Apollo GSE end items. Each item will be evaluated for qualification testing in this report.

2. Categorization of Equipment According to Criticality. The list of GSE end items will be divided into the following categories: mission essential, criticality I, criticality II, and mission support, in descending order of importance.

3. Definition of Equipment Location, Environments, and Environmental Protection. The GSE end items will be classified according to the usage locations presenting the most severe environmental problems. The environmental protection afforded by design and shelter will be specified.

4. Definition of Any Special Tests that Must be Performed, Such as Component Testing. These should be determined by failure mode and effects analyses on all mission-essential GSE. Components involved in the critical failure modes will be investigated to determine if qualification testing is warranted.

5. Estimation of the Duration and Cost of Each Test. Preparation of schedules, cost estimates, and effectivity for all qualification testing of GSE.

6. Estimation of GSE Engineering Cost. Documentation changes, test liaison, and refurbishment (engineering orders, procedures, etc.).

[redacted]

7. Estimation of Reliability Costs. Engineering surveillance, data compilation, report preparation, and failure analysis of test results.

8. Estimation of Refurbishment Costs. Material and shop labor estimates.

9. Estimation of Total Program Cost. Based on results of 5, 6, 7, and 8.

10. Preparation of a Document Describing the Study Results. A report will be prepared describing the results of 1 through 9. This report should contain sufficient data for the budget and planning estimate to be presented to NASA.

PLANNED ACTIVITIES

Preliminary and final design analysis will be performed on all equipment associated with individual boilerplates. Studies will include reliability predictions, stress analysis (Mandex d-c computer aided), failure mode and affects, participation in design reviews, procurement specifications, specification control drawings and design control drawings. The results of the analyses performed on mission essential equipment will be used to develop a mathematical model for the equipment associated with each vehicle.

Development of additional computer capability will continue to encompass mechanical and electromechanical stress studies. The use of a Laplace transform program will be investigated.

Surveillance and analysis will be performed for problem areas and failures reported on nonconformance reports generated in the various test and usage areas. Failures will be analyzed for causes and, if required, design changes will be made.

Interfaces between spacecraft systems and PACE equipment will be investigated to properly review probable failure modes and their effects.

Failure detection verification tests based upon failure mode and effect analyses will be developed.

V. SUPPORT OPERATIONS

DATA MANAGEMENT

NONCONFORMANCE REPORTING SYSTEM

The first phase of an advance study was completed on determining the feasibility of automating data reduction of nonconformance data during production. The results, accepted by NASA, quality engineering, and the Manufacturing Coordination Panel provide the capability to produce automated displays of nonconformances on specific boilerplates.

The Phase II programming of the nonconformance reporting system has been completed on schedule. This portion of the program will increase the capabilities of the system in order to satisfy many requirements for flexibility, selectivity, and simplicity in automated retrieval of nonconformance data from the data bank.

The program capabilities include selection of specific data elements: a six level sort (with or without totals); selection of a single element in a data field; selection of multiple (twelve) elements in a data field; and selection of multiple (seven) data fields. Flexible output formats and immediate response (24 hour service) to unscheduled requests are also included.

Phase III programming of the nonconformance reporting system is now undergoing a feasibility study. The Phase III program will have the capability of preparing printouts with statistical disciplines.

During this report period, 1110 nonconformance reports (NCR's) were reviewed, processed, and transposed to transmittal sheets to be machine stored for future reference. Tabulated printouts showing weekly and accumulated monthly NCR activity are being distributed regularly. Summary problem reports have been prepared and issued showing distribution of various nonconformance conditions by vehicle subsystem. During this period, the major cause categories for NCR problems were as follows:

Cause	Percent of Total
Workmanship	37.6
Design inadequacy	9.7
Inadequate tooling	3.9
Mishandling	3.5
Manufacturing	3.4

[redacted]

SCRAP REPORT

During this report period, 262 scrap reports involving 31,916 parts were tabulated and issued as monthly reports. The extremely high part rejection is a direct result of scrapping 19,500 high-shear rivet collars, 10,637 screws (MS), and 750 capacitors. The scrap report tabulation lists obvious scrap items not included in the NCR system.

SUBCONTRACTOR DATA ACTIVITIES

The flow of supplier development test data (supplier failure reports) to S&ID has been much less than predicted for this period in the Apollo program. Problem trends and areas could not be defined because of the small amount of problem data received. Monthly supplier failure summaries delineating problem symptoms, part condition, and problem causes are being prepared and issued at the present time.

Problem reports received from subcontractors during this period included the following:

1. Minneapolis-Honeywell. Eight reports on problems encountered during development stages of the stabilization and control system involved two cases each for gyros, d-c stepper motors, gear trains, and temperature compensating network assemblies. Corrective action to improve the reliability in these problem areas has been taken.

2. Collins Radio Corporation. One report on coaxial switch failure that required higher than normal voltage to operate. The switch was returned to the supplier for analysis.

3. Pratt & Whitney Aircraft. Thirteen failure reports involving development of the fuel cell system on the circulating fuel pumps, reactant regulators, reactant purge valves, one coolant pump, and one fuel regenerator bypass control. Correction was achieved by material changes, modifications, and engineering improvement changes.

4. Northrop-Ventura. Ninety-eight reports involved components of the earth landing system. Material tears, burns, and stitching failures of the parachutes and deployment bags continue to be the predominant problems. Analysis indicates that most of the problems are minor and require no formal corrective action. Heavier materials and stitching changes have been made where appropriate.

5. Aerojet-General Corporation. During test operations eighteen failures occurred. Eleven of these failures (61 percent) were caused by combustion instability. Corrective action is in progress to correct this major cause for failures.

6. Beech Aircraft Corporation. The following failures which were observed during test operations. Fill tube broke and pressure vessels ruptured. Other discrepant areas are tooling problems, revealed by X-ray inspection to be unsatisfactory welds in the girth area. Difficulty has been encountered in fabrication of acceptable hydrogen coil housing assemblies. Engineering has redesigned critical areas pertaining to above assemblies and an acceptable configuration is expected.

7. Lockheed Propulsion Company. Attachment bolts failed causing nozzle hull separation from the motor case when 4000 psi were applied to the motor PC-26. Cause of failure was an error in the nozzle throat diameter calculation resulting in a nozzle with an undersized throat diameter. The pressure lines burned through from the inside (external to motor) after ignition, resulting in loss of motor performance data.

8. Marquardt Corporation. The malfunction of an oxidizer solenoid was caused by a soldered joint contacting the case, which created a short. Redesign increased the gap space to preclude a repeat of the failure. Two other malfunctions occurred during testing of the fuel-cooled injector head, which resulted in shattering of the combustion chambers. Cause of the failure was due to an accumulation of fuel vapor in the combustion chamber and nozzle. Corrective action was to select an alternate design for this injector head. Burnout of the combustion chamber occurred during development testing on one engine. It was noted that two other chambers evidenced a coating of deterioration. The cause is currently being investigated for analysis of chamber burnouts.

9. Rocketdyne. Three nonfireable engines were returned from S&ID for rework because of leakage in the oxidizer tube on two assemblies and an apparent plugged fuel valve on the third unit. Examination showed evidence of excessive torque having been applied to the propellant inlet fittings. A thorough investigation will be conducted to determine these failures.

PERFORMANCE ANALYSIS AND TEST HISTORY (PATH) SYSTEM

Initial outputs have been produced for the pilot PATH system, and programming is continuing on the selective retrieval phase.

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The Quality Assurance Operating Procedure, "Test Result and Parametric Data," was issued. It establishes responsibilities for the recording of functional test data.

TRACEABILITY AND CONFIGURATION (TAC) DATA SYSTEM

The TAC PERT network was revised to conform to the MEAT (Management Evaluation and Analysis Technique) system. The latest revision of this system indicates an expected completion date for the TAC system of 24 January 1964. This is a 3-week slippage from the estimated completion date (6 January 1964) stated in the last quarterly report. However, it is still expected that the earlier date will be met.

The interim TAC reporting system has been completed, and all reports are going out on schedule. To date, approximately 5000 data records have been submitted into the system.

OPERATING TIME DATA SYSTEM

The system redefinition has been completed, and approval has been given to start initial programming efforts. The estimated completion date for this system is 15 January 1964.

SUPPLIER QUALITY HISTORY (SQH) DATA SYSTEM

A supplier rating system has been developed and is presently being programmed for computer utilization. A supplier whose product class rating falls below a set minimum will appear on an exception report providing management notification of those suppliers needing closest surveillance. Further, a process average exception report has been developed to indicate those receivals where tightened or reduced inspection is to be performed.

Prime emphasis has been placed upon designing within each data system reports which will indicate a need for management action without further data manipulation.

The major automated reports produced by this system are: (1) worst case by part number; (2) rejected trend by G.O. and project; (3) rejection summary of parts which have had government inspection, and (4) qualification status list system.

The SQH also provides a process average action summary report which will analyze receiving inspection disposition data, by computer methods, and prepare management-oriented summary reports of only those suppliers whose process average falls below a predetermined minimum.

[redacted]

[redacted]

PARTS LIBRARY TAPE (PLT) SYSTEM

To date, a total of 41,000 part numbers have been recorded in the parts library file. The file has been expanded in scope to include twelve elements of data that are unique to the part number. These data elements are: part name, traceability code, generic code, audit, system, project, specification, classification, criticality, limited life, time sensitive, and conversion factor. Research is continuing to determine if other data elements can be added to the file.

MASTER CODE FILE

Negotiations have been completed to produce the data systems code books directly from the computer. The codebooks will be divided according to data system and project. Programming will be initiated within one month and the initial output should be ready by the end of the year.

AUTOMATED DATA PACKAGE

The data package for Boilerplate 6 was reviewed to determine if all existing definitions would suffice to meet the data package requirements. The acceptance test data embodied certain elements of data which had not been provided in original definitions; therefore, adjustments were necessary. The automated data package outputs are scheduled to be available 15 February 1964. The reports planned for automatic production are: (1) failure and corrective action; (2) material review summary; (3) configuration report; (4) replacement record, and (5) operating time report.

QUALITY HISTORY (QH) DATA SYSTEM

QH data tabulations have significantly assisted discrepancy reporting for quality control purposes. Redefinitions for improvement purposes have been submitted for programming. The primary area of improvement involves summary reports to be used for management visibility.

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TRAINING AND EDUCATION

SUMMARY

Reliability educational courses presented during the report period are tabulated in Table 5-1.

Table 5-1. Reliability Education Courses

Course	Number of Lectures	Average Attendance	Total Hours
Fundamentals of Reliability Mathematics	3	15	45
Design Analysis Techniques	20	11	220
Computer Methods of Analysis	10	14	140
Total	33		405

Course material was developed for two new reliability education courses. The first, "Advanced Reliability Mathematics," is intended as a continuation to the course "Fundamentals of Reliability Mathematics" and covers such topics as confidence, apportionment, and the Weibull, Gamma, and Poisson distributions for application to reliability. The second course, "Design of Experiments," satisfies a requirement of the test program with such topics as statistical inference, complete randomized design, randomized block, Latin square, and factorial testing.

Reliability education began extensive efforts toward utilization of closed-circuit television for indoctrination and motivation of personnel. Table 5-2 shows the progress made during the report period.

PLANNED ACTIVITIES

Three supplier symposia are planned for the eighth quarter to assist Apollo subcontractors and major suppliers with reliability education programs.

[redacted]

[redacted]

Table 5-2. Reliability CCTV Programs

Title	CCTV Attendance	Status	Scheduled Transmission
"100,000 Astronauts"	1276	Completed	8/26/63
The Apollo Challenge	692	Completed	9/6/63
Design Review Indoctrination		Completed	9/18/63
The Apollo Test Plan		Completed	9/23/63
The Apollo Mission		In Production	9/26/63
Design Review Participation		Completed	10/2/63
Integrity Plus		Completed	10/9/63
Parts Handling		In Production	10/31/63
Identification and Traceability		In Production	11/14/63
Reliability Engineering Services		In Production	12/3/63
Total	1968		

Reliability education CCTV programs will be viewed by a total audience of 24,000 (estimated) by 16 December 1963. In addition, three new television programs will be started during this period for completion early in 1964.

Table 5-3 shows the courses which are currently being offered and which will be offered during the next quarter.

Table 5-3. Reliability Educational Courses

Course No.	Title
E 201	Design Analysis Techniques
E 202	Computer Methods of Analysis
E 203	Fundamentals of Reliability Mathematics
E 204	Symbolic Logic
E 205	Design of Experiments
E 206	Advanced Reliability Mathematics

[redacted]

COMPONENT TECHNOLOGY

All of the high-reliability (Hi-Rel) preferred part specification control drawings (SCD) have been released with approved supplier lists (ASL). Minor revisions required on approximately 50 percent of these are in progress. Additional sources have been obtained for a number of released SCD. It is estimated that there will be an average of two sources for each Hi-Rel SCD.

Agreement has been reached on the usage of the preferred parts manual. Hi-Rel parts, as listed in the manual, will be used in the S&ID Parts Manual.

Major effort was expended in reviewing approximately 400 specifications from Apollo subcontractors: RCA, Minneapolis-Honeywell, Collins, Elgin, and Simmonds. An Apollo current usage parts list has been prepared from a review of specifications submitted by Minneapolis-Honeywell and Collins Radio.

In the area of high-reliability parts control, Specification MA0116-027, "Interplant Parts Protection Requirements for High Reliability Items," Specification MA0115-011, "Identification and Traceability Requirements for Suppliers High Reliability Parts," process Specification MA0116-016 "Supplier Packaging and Handling of High Reliability Items," and process Specification MA0116-028, "Packaging for General Usage Parts" have been released.

Bids on the test plan for hard vacuum testing of approximately 55 different types of parts have been received from several outside vendors. Ardel Corporation has been tentatively chosen to do the work. Delivery of parts for the hard vacuum test is progressing as scheduled.

Specifications for clean-room requirements are being investigated. It is essential that cleanliness requirements be coordinated and also that clean-room terminology be standardized for the Apollo program.

All engineering order procurement requests issued are being reviewed to develop a substitution list providing equivalent preferred parts for major usage components. This substitution list is particularly critical for all welded modules because it is necessary to provide parts with a controlled lead material. Additional classes of parts are being documented and added to the preferred parts list.

[redacted]

Studies to keep abreast with most recent failure rate and application data continue. Preview of all Apollo part specifications will also continue, as well as participation in all Apollo design reviews and the establishment of required procedures for the handling of high reliability parts.